

# MAPS Cost and Schedule Document

Ming Liu

LANL

# Assumptions

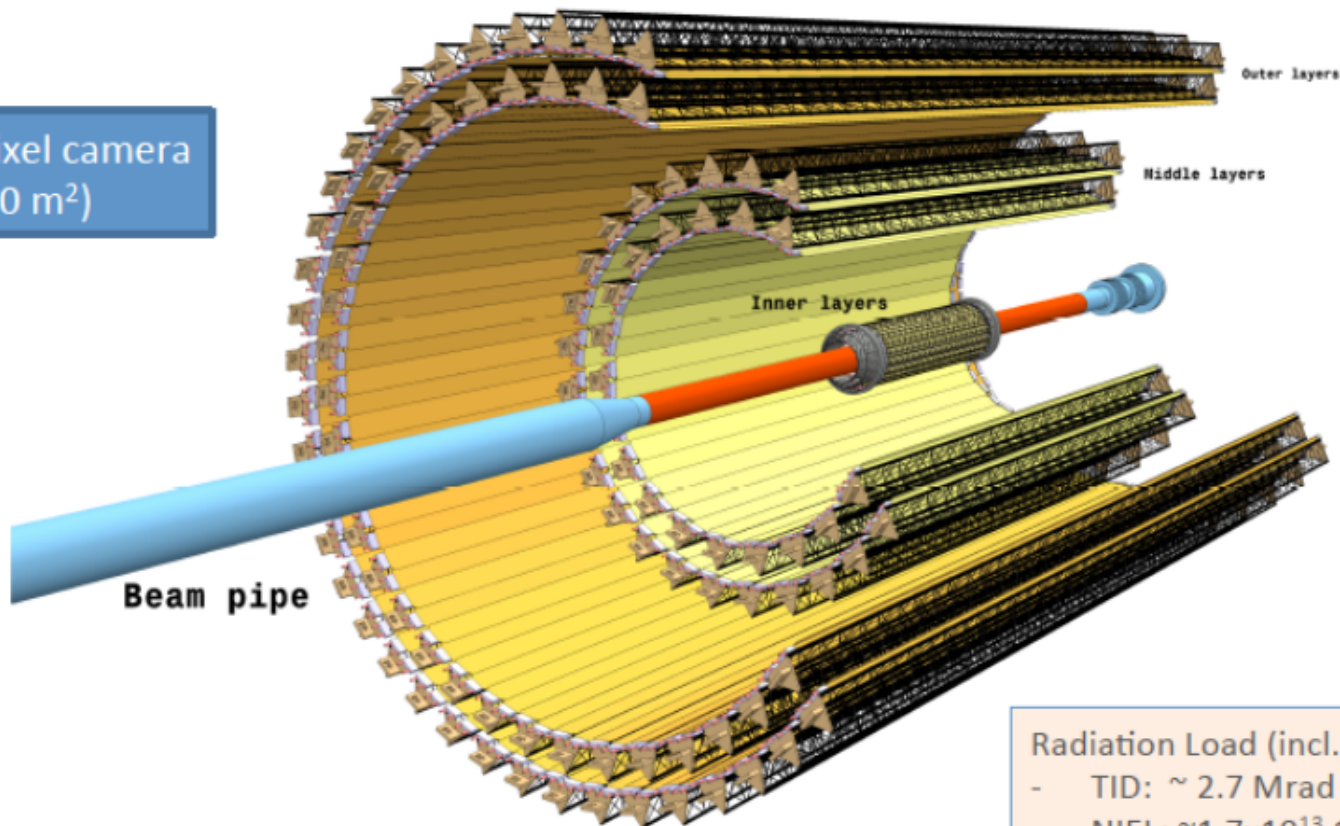
- Copy of ALICE 3-layer MAPS Inner Tracker (need check fixed \$\$)
- Extend ALICE ITS production
- Follow proposed sPHENIX CD process
- Critical R&D for CD-1 and CD-2/3 by LANL LDRD
- Production starts at CD-3b
- Initial cost and schedule from ALICE ITS documents
- Other cost from recent experiments, FVTX/PHENIX, HFT/STAR
- Manpower costs from Lab Engineers and Techs
- Duration from ALICE C&S where available and previous FVTX/PHENIX experience
- Initial manpower allocation w/o smoothing (in progress)
- Schedule contingency in progress (MoU w/ ALICE )
- Applied 30% cost & schedule contingency (prorated from ITS C&S)

# New ITS Layout

A Large Ion Collider Experiment



12.5 G-pixel camera  
( $\sim 10 \text{ m}^2$ )



Radiation Load (incl. safety factor 10)

- TID:  $\sim 2.7 \text{ Mrad}$
- NIEL:  $\sim 1.7 \times 10^{13} \text{ 1MeV } n_{\text{eq}} / \text{cm}^2$

## 7-layer barrel geometry based on CMOS Sensors

$r$  coverage: 23 – 400 mm

$\eta$  coverage:  $|\eta| \leq 1.22$

for tracks from 90% most luminous region

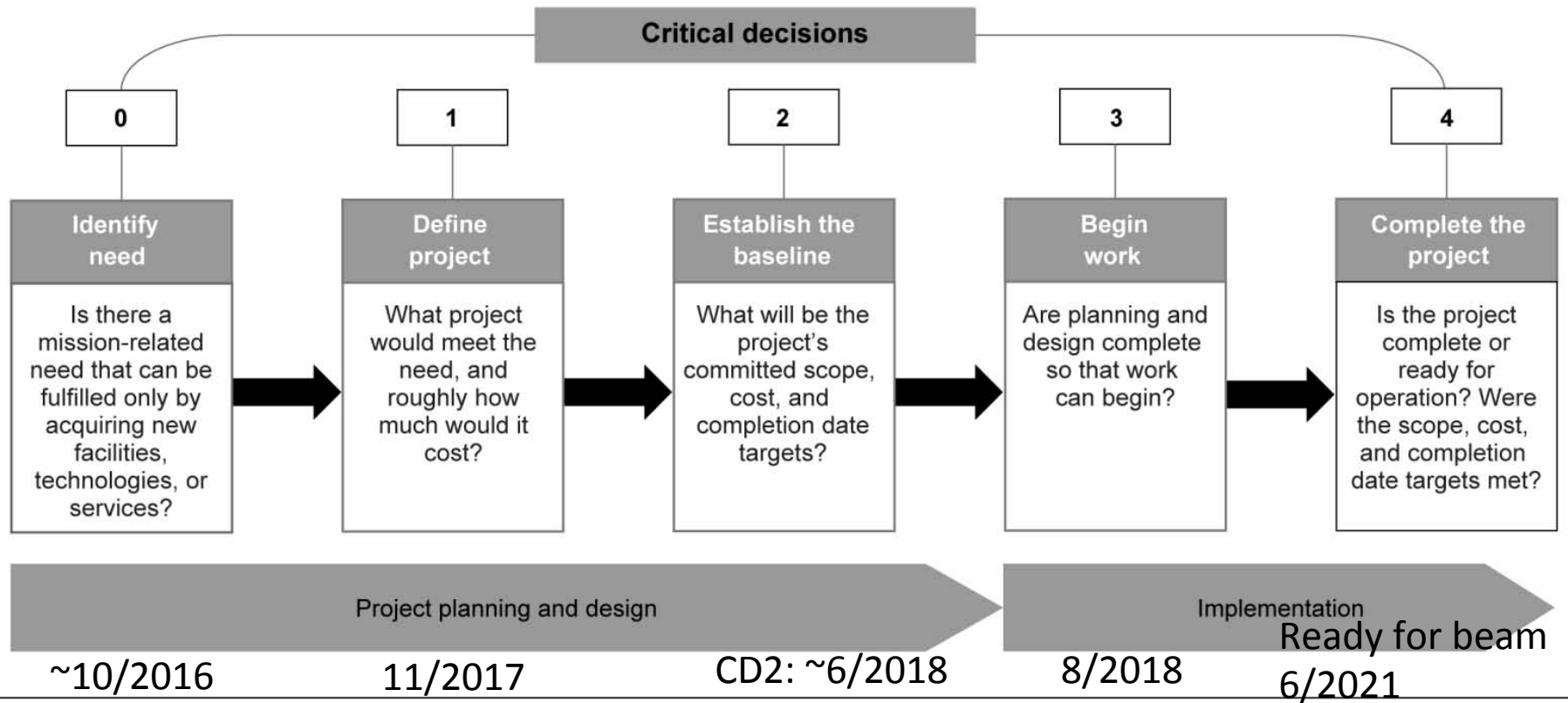
3 Inner Barrel layers (IB)

4 Outer Barrel layers (OB)

Material /layer : 0.3%  $X_0$  (IB), 1%  $X_0$  (OB)

sPHENIX

# sPHENIX DOE Critical Decision Process



Installation: 2/1  
Commissioning: 4/1



# MAPS Cost and Schedule Workshop

## 3/30-4/1, 2016, Santa Fe, NM

<https://indico.bnl.gov/conferenceDisplay.py?confId=1741>

Well attended by experts from:  
sPHENIX, ITS/ALICE,  
HFT/STAR, FVTX/PHENIX, EIC

LANL, CERN, LBNL, BNL, MIT, FSU, UColorado  
Yonsei/Korea, and several other US institutions

### Take Home:

- Extension of ALICE production possible
- Inner tracker cost <\$5M inc. contingency
- Can meet sPHENIX CD schedule



8/22/16

### sPHENIX MAPS Cost & Schedule Workfest

from 30 March 2016 to 01 April 2016 (US/Mountain) *El Dorado Hotel*  
US/Mountain timezone

**Overview**

Timetable

Contribution List

Author Index

Registration

Registration Form

List of registrants

The purpose of this 3 day workfest is to define and document the cost and schedule for the MAPS based tracking options under consideration for the sPHENIX detector. The interactive workfest format will be organized into topical breakout teams with MAPS, engineering, and C&S experts we are gathering from ALICE, sPHENIX, and other projects and will minimize time spent in presentations.

Update 3/2/16: The workfest will be held at the El Dorado Hotel. The hotel is located just a short walk west of the historic downtown square. See <http://www.eldoradohotel.com> for more hotel details. We've arranged for a block of rooms is available now and can be booked at the workfest/gov't rate (\$99/night) if you follow: [https://gc.synxis.com/rez.aspx?Hotel=63150&Chain=17123&Dest=Santa Fe&template=GCF&shell=GCF&locale=en-US&arrive=3/29/2016&depart=4/1/2016&adult=1&child=0&group=sPHENIX](https://gc.synxis.com/rez.aspx?Hotel=63150&Chain=17123&Dest=Santa%20Fe&template=GCF&shell=GCF&locale=en-US&arrive=3/29/2016&depart=4/1/2016&adult=1&child=0&group=sPHENIX) which will lead you to a web form for the conference. If you decide to call the hotel directly at 505-995-4500, our call-in/group code for the reservations is: sPHENIX.

FAQ: *Should I fly out of ABQ on Friday evening or Saturday morning?*

The answer to this is if you can find a suitable flight or not. We expect that some participants will book flights out Friday evening and leave the workfest in the afternoon to take those flights. Not all participants will find a flight and so Saturday morning will be an option for them. Our plan is to be finalizing the C&S document on Friday afternoon. The organizers will stay until the end of the day and go to dinner with the remaining participants. The drive from Santa Fe to the airport (ABQ) will take approximately 1 hour.

**Dates:** from 30 March 2016 09:00 to 01 April 2016 17:30  
**Timezone:** US/Mountain  
**Location:** *El Dorado Hotel*  
309 W San Francisco St.  
Santa Fe, NM 87501  
Room: DeVargas  
**Material:** [Folder](#)  
[Slides](#)

- First draft Cost and Schedule project was produced based on inputs from Santa Fe Workshop
- Further inputs from BNL 6/30 MAPS mini review

# Overview of the Project Schedule

Key dates:

MoU btw LANL/sPHENIX and ITS/ALICE: ~12/2016

Meet CD-1: 11/2017

- MAPS Electronics R&D completed: ~3/2018
- MAPS design completed: ~8/2018

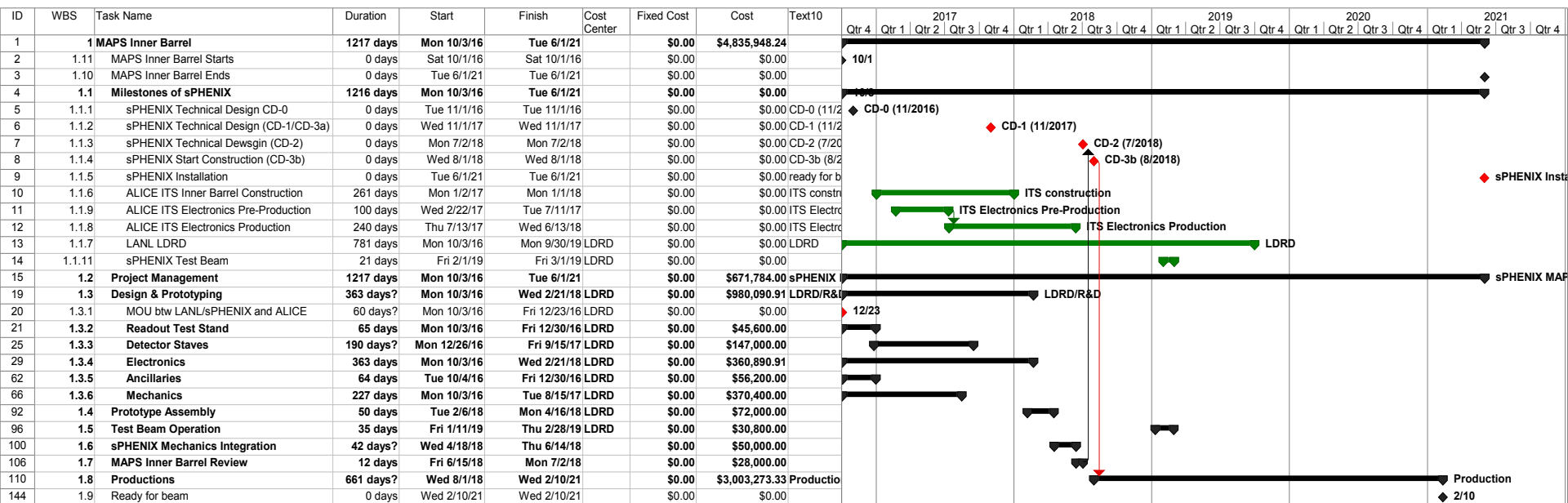
Meet CD2/CD-3b: 8/2018

- MAPS final design/CD-2: 7/2/2018

Ready for beam: 6/1/2021

- MAPS ready: 2/2021

Sun 8/21/16



# Collaboration & Management

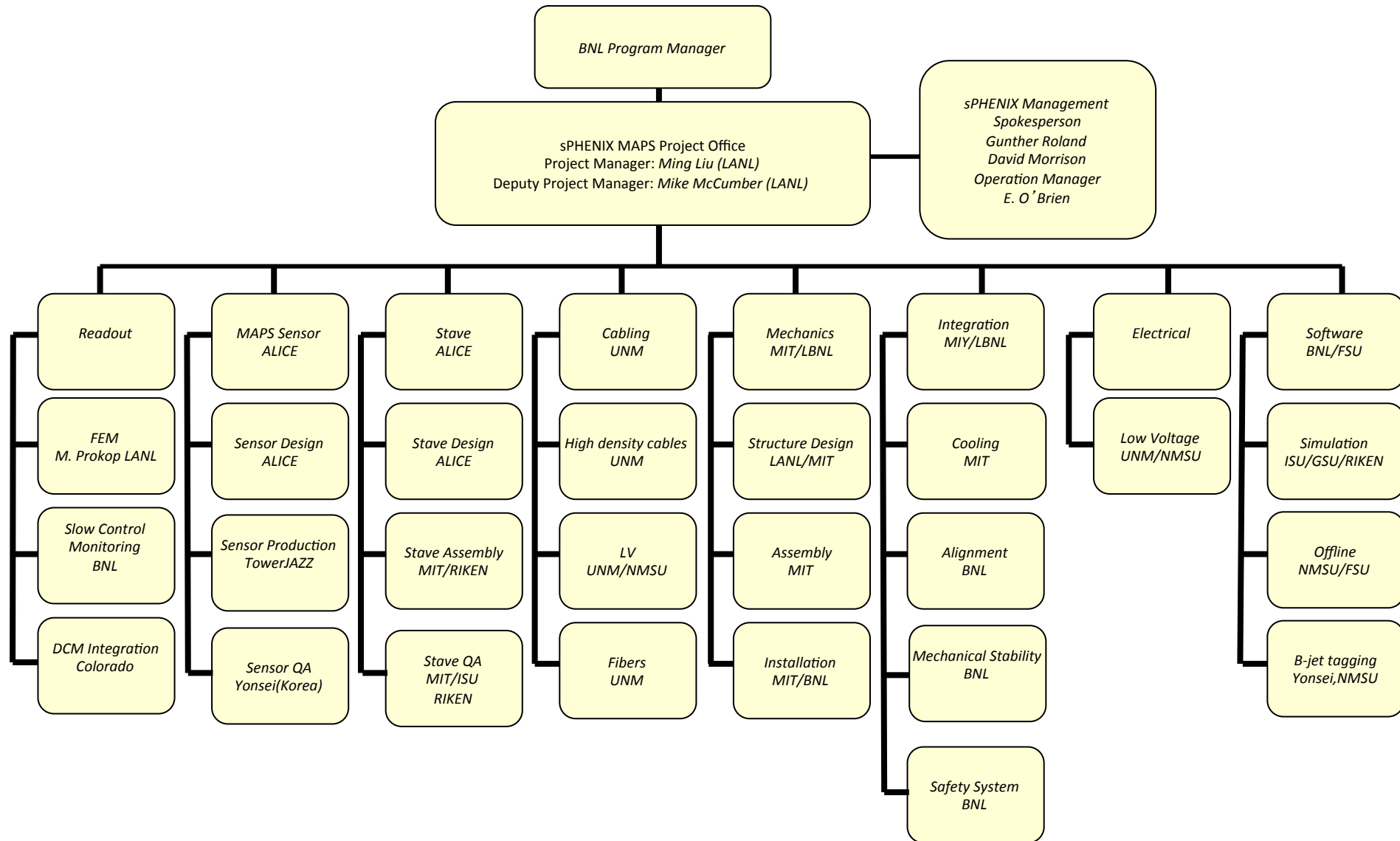
- Workshops organized in Santa Fe, 4/2016
  - Strong support from ITS/ALICE and other groups
    - LBNL, BNL STAR/HFT group
    - MIT, Yonsei / Korean Institutions
  - Produced 1<sup>st</sup> draft of Cost and Schedule project file
  - Established collaboration with ALICE ITS groups
- MAPS Detector Group Kickoff Meeting 8/19/2016
  - Institutions and their interest
  - Resources and plan
- US institutions
  - MIT HI and ME groups
    - Stave assembly and test at CERN & BNL, cooling, integration etc.
  - LBNL
    - mechanical carbon frame etc
  - BNL
    - Services, DAQ, safety, tech support etc
  - UNM and NMSU
    - Cabling, assembly, simulations and physics analysis
  - U Colorado
    - DAQ and DCM-II integration, simulations and analysis
  - ISU
    - Simulations and analysis, assembly and test
  - GSU
    - Simulations, small controls
  - FSU
    - Offline
  - U California, Riverside/LA/Davis etc
    - Local mechanical and electronics shops, simulations, assembly and test
- Other international collaborators
  - RIKEN/RBRC – assembly, test and simulations
  - CCNU/ALICE/ITS
  - Yonsei/ALICE/ITS

## Working on MOU with ITS/ALICE

- Initial discussion with ITS Management
- Associate Membership on ITS/ALICE project
- Obtain 4 staves & readout for R&D ASAP
- Stave production extension, schedule and “mortgage”
- Obtain readout design files
- Mechanical design files
- sPHENIX manpower at CERN
- 2 presentations planned
  - 9/1/2016: ALICE Management Board meeting
  - 11/11/2016: ALICE Collaboration Board meeting

Expect MOU agreement: 12/2016

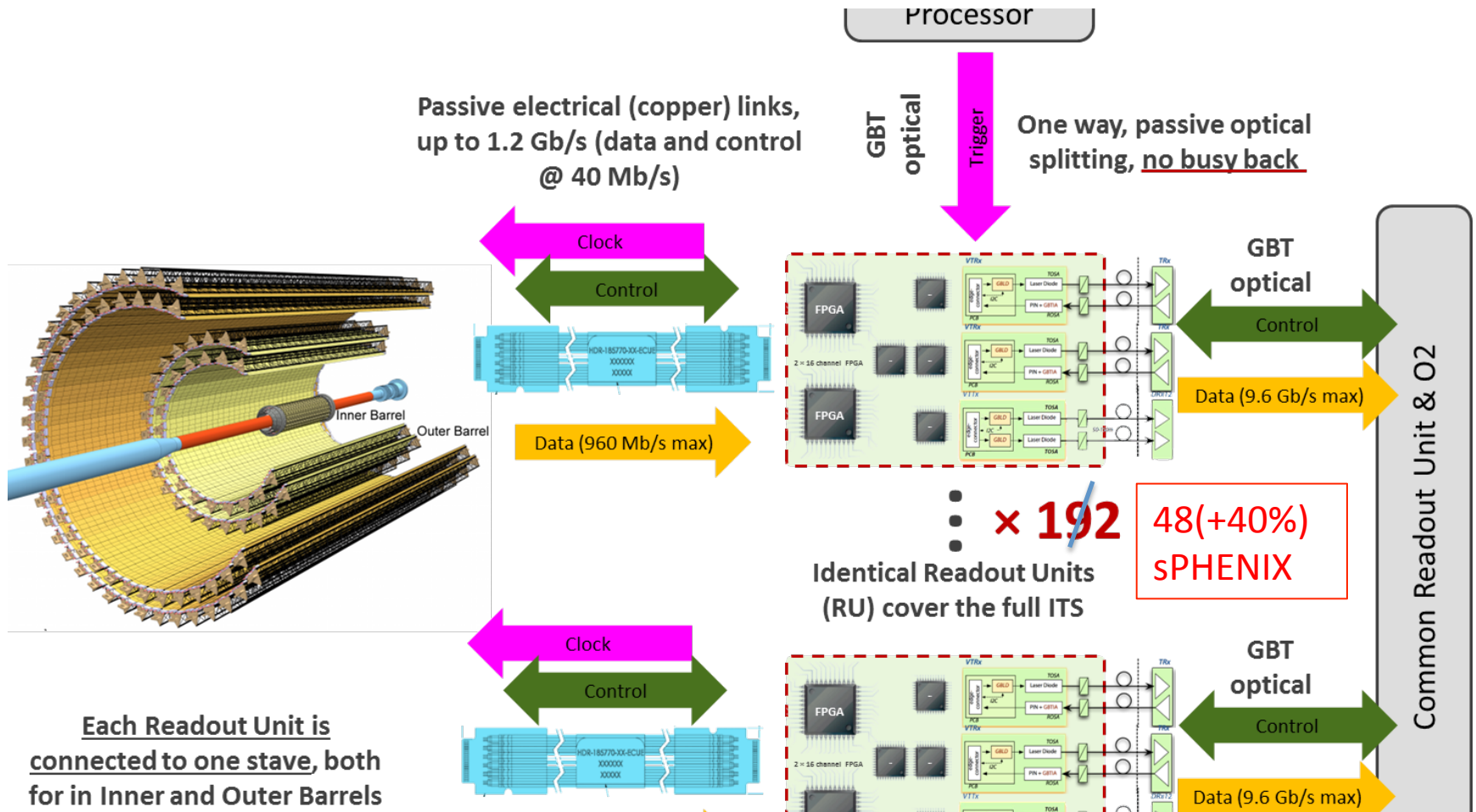
# Organization Chart



# Details of C&S

# Cost Basis For Electronics

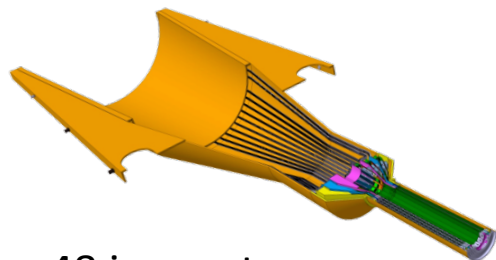
J. Phys. G: Nucl. Part. Phys. **41** (2014) 087002



# Readout Units Required for ITS & sPHENIX

Readout Units and GBT links for maximum design rates

Layer	Staves	Copper assemblies	Copper capacity	RUs per stave	RUs per layer	VTRx count	VTTx count	Data fibers	Control fibers	Data fibers capacity	Data fibers usage
			[Gb/s]							[Gb/s]	[%]
0	12	12	103.7	1	12	24	12	36	12	115.2	90.0
1	16	16	138.2	1	16	32	16	48	16	153.6	90.0
2	20	20	172.8	1	20	40	20	60	20	192	90.0
3	24	48	122.9	1	24	48	24	48	24	153.2	80.0
4	30	60	153.6	1	30	60	30	60	30	192	80.0
5	42	168	376.3	1	42	84	42	126	42	403.2	93.3
6	48	196	430.1	1	48	96	48	144	48	460.8	93.3
Total		520	1497.6		192	384	192	576	192	1670	



48 inner staves

48 RDO boards

sPHENIX: 48 +40% = 68

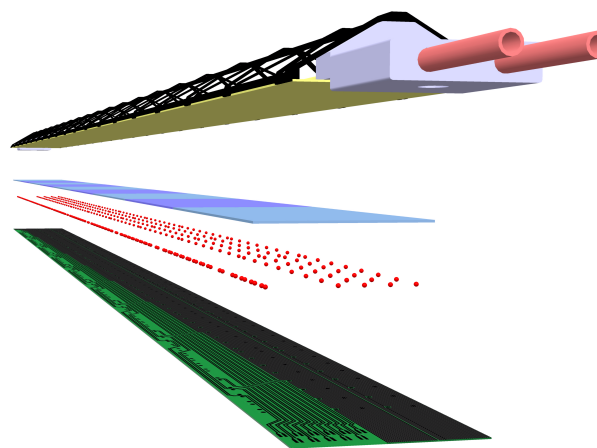
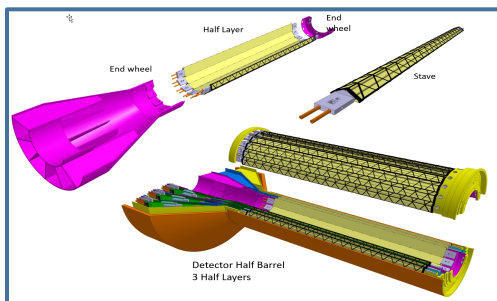
ITS IB:

Produce 120 staves in one year

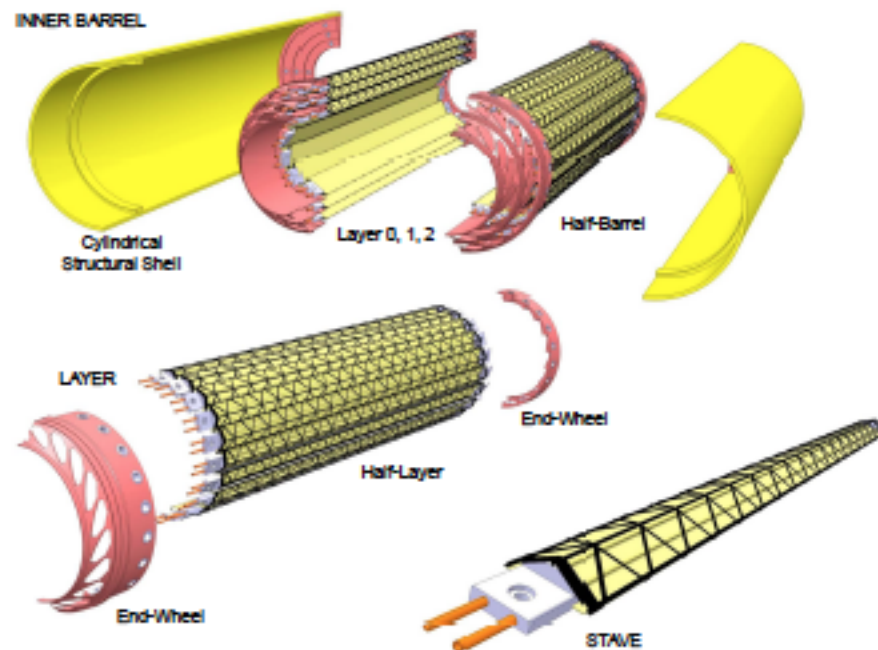
120% contingency



# ALICE Stave and Global Support Structure Cost Basis



ALICE Stave



(a) ITS Inner Barrel design.

J. Phys. G: Nucl. Part. Phys. **41** (2014) 087002



# Cost breakdown

A Large Ion Collider Experiment



ALICE

Activity	Material Costs	Manpower Costs	TOTAL COST / ITEM
<u>1. Pixel Chip</u>	4847	170	5017
1.1 CMOS Wafers	3611		3611
1.2 Thinning & Dicing	800		800
1.3 Series test	436	170	606
<u>2 Inner Barrel</u>	296	262	558
2.1 FPC (construction and test)	23	13	36
2.2 HIC (assembly and test)	250	150	400
2.3 SF & Cold Plate (constr. and test)	3	43	46
2.4 Stave assembly & test	20	56	76
<u>3 Outer Barrel HIC</u>	1447	1118	2565
3.1 FPC (construction and test)	247	88	335
3.2 HIC (assembly and test)	1200	1030	2230
<u>4 Middle Layers Staves</u>	142	322	464
4.1 Powerbus cables	70	3	73
4.2 SF & Cold Plate (constr. and test)	42	113	155
4.3 Stave assembly & test	30	206	236
<u>5 Outer Layers Staves</u>	284	896	1180
5.1 Powerbus cables	127	33	160
5.2 SF & Cold Plate (constr. and test)	97	245	342
5.3 Stave assembly & test	60	618	678

Chips:  
 $1k/50k = 2\%$   
 - \$100K

Staves:  
 $68/120 = 60\%$   
 -\$340K

Share R&D cost  
 -\$500K

“Buy staves”  
 and MoU

Total ~\$1M

# Cost breakdown

A Large Ion Collider Experiment



Activity	Material Costs	Manpower Costs	TOTAL COST / ITEM
<a href="#">6 Inner Barrel Global Assembly</a>	70	156	227
6.1 End-Wheels (E-W)	4	30	34
6.2 Assembly of Staves on E-W	16	12	28
6.3 Cylindrical Structural Shell	1	10	11
6.4 Detector Half-Barrels	6	7	13
6.5 Service Half-Barrels	36	84	120
6.6 Detector + Service Half-Barrels	7	14	21
<a href="#">7 Outer Barrel Global Assembly</a>	135	407	542
7.1 ML End-Wheels	13	50	63
7.2 ML Assembly of Staves on E-W	10	21	31
7.3 OL End-Wheels	23	59	82
7.4 OL Assembly of Staves on E-W	12	32	44
7.5 Conyical Structural Shell	8	62	70
7.6 Cylindrical Structural Shell	20	55	75
7.7 Detector Half-Barrels	7	13	20
7.8 Service Half-Barrels	36	85	121
7.9 Detector + Service Half-Barrels	7	30	37
<a href="#">8 Integration in ALICE</a>	91	262	354
8.1 Cage	61	153	215
8.2 Installation Tooling	30	109	139

# Cost breakdown

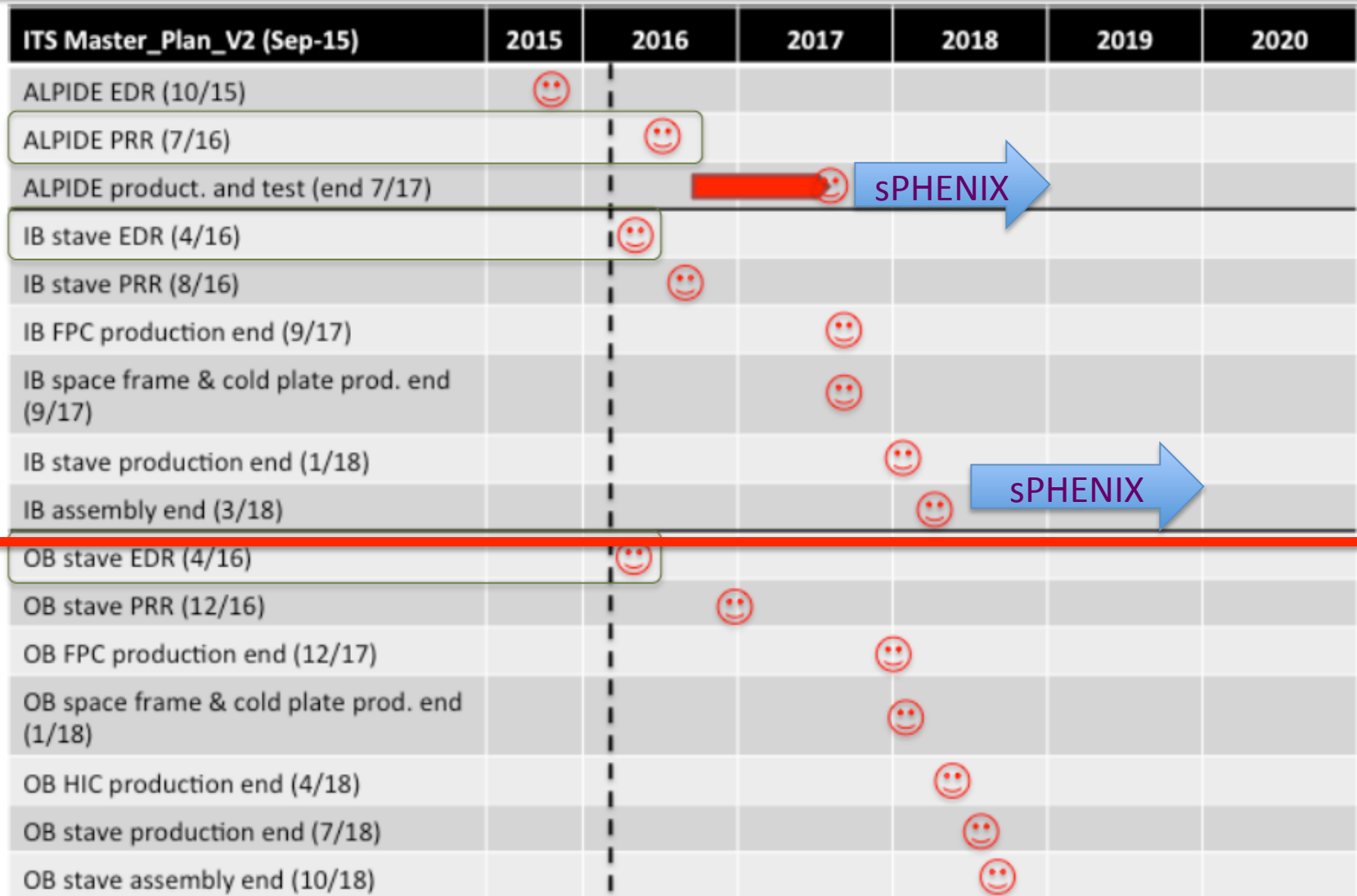
A Large Ion Collider Experiment



Activity	Material Costs	Manpower Costs	TOTAL COST / ITEM
<a href="#">9 Readout Electronics</a>	715	50	765
9.1 Data e-Links	82	50	132
9.2 Patch-panels	20		20
9.3 Readout Unit	469		469
9.4 Optical Links	144		144
<a href="#">10 Power distribution</a>	1149	50	1199
10.1 Power Supplies	750		750
10.2 Power Distribution	242	50	292
10.3 Power Regulation	157		157
<a href="#">11. DCS</a>	150		150
<a href="#">12. Cooling</a>	620	0	620
12.1 Water Cooling Plant	470		470
12.2 Ventilation Humidity Plant	150		150
<b>GRAND TOTAL</b>	<b>9947</b>	<b>3693</b>	<b>13640</b>

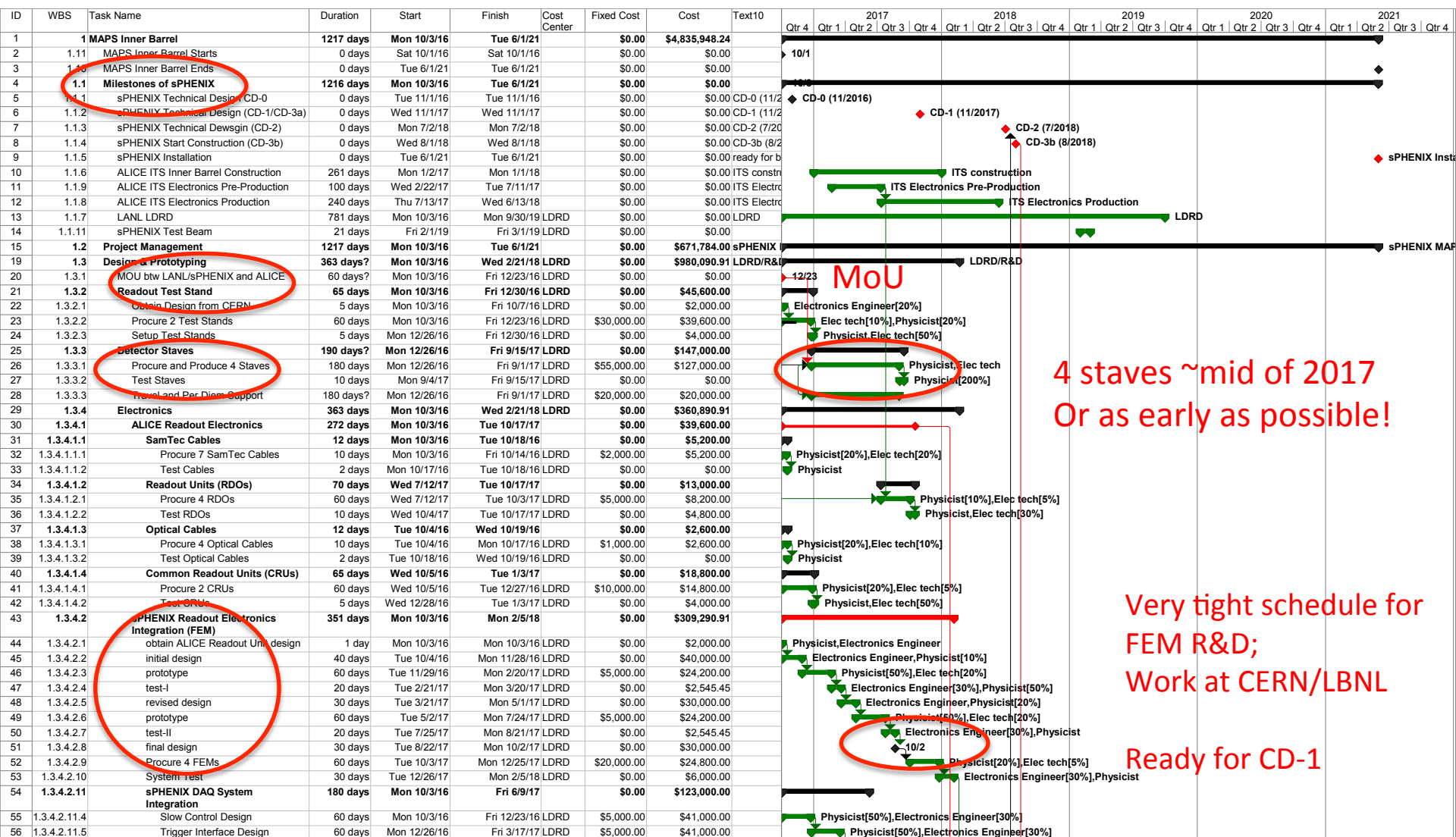
# Milestones – ALPIDE, IB & OB Staves

A Large Ion Collider Experiment



# Electronics R&D (I)

Sun 8/21/16



4 staves ~mid of 2017  
Or as early as possible!

Very tight schedule for  
FEM R&D;  
Work at CERN/LBNL

Ready for CD-1

# Electronics R&D (II)

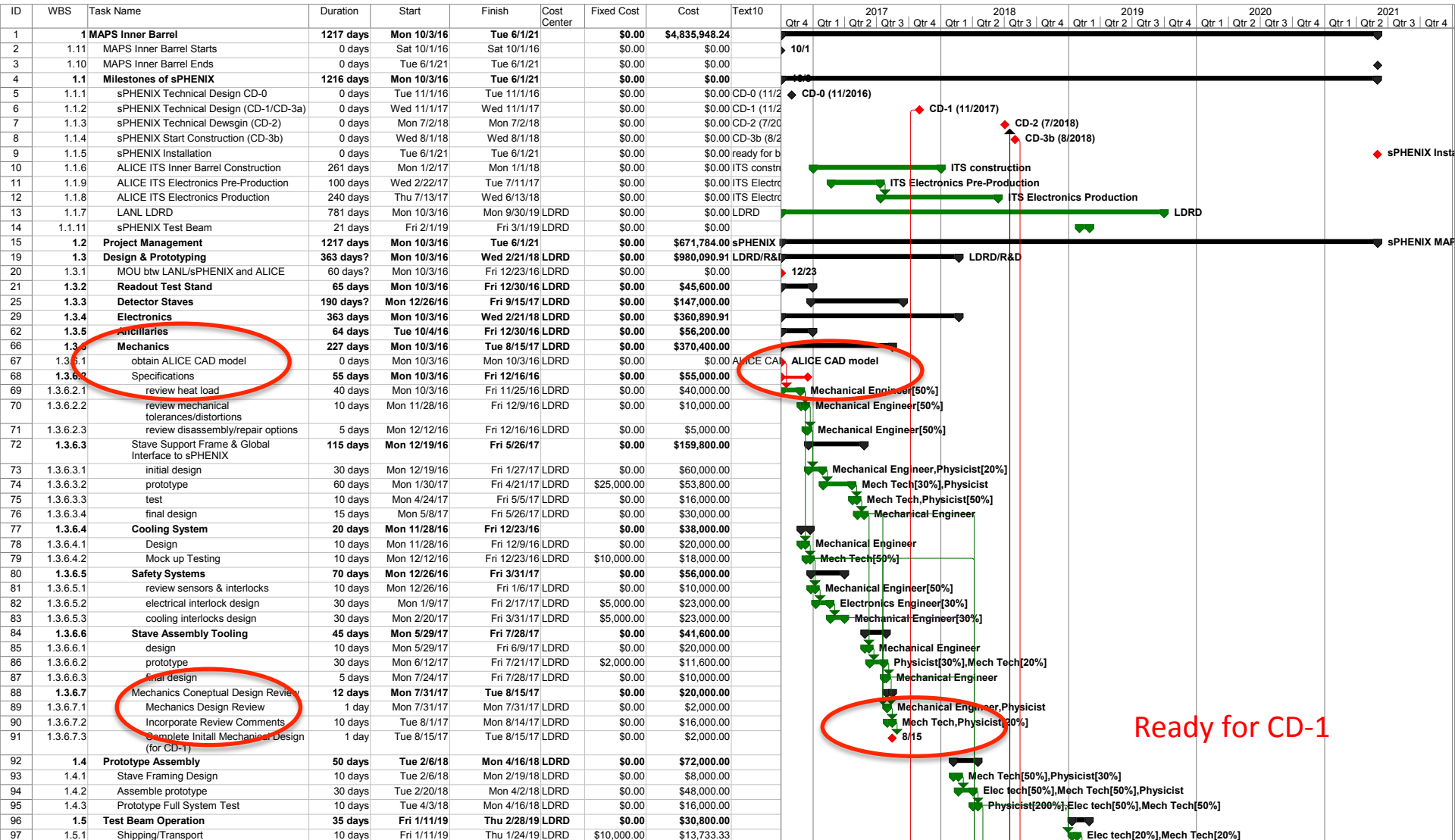
Sun 8/21/16

ID	WBS	Task Name	Duration	Start	Finish	Cost Center	Fixed Cost	Cost	Text10	Qtr 4   Qtr 1   Qtr 2   Qtr 3   Qtr 4   Qtr 1   Qtr 2   Qtr 3   Qtr 4   Qtr 1   Qtr 2   Qtr 3   Qtr 4   Qtr 1   Qtr 2   Qtr 3   Qtr 4   Qtr 1   Qtr 2   Qtr 3   Qtr 4																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				
57	1.3.4.2.11.6	DAQ Interface Design	60 days	Mon 3/20/17	Fri 6/9/17	LDRD	\$5,000.00	\$41,000.00																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						

Ready for CD-2

# Mechanics R&D (I)

Sun 8/21/16





# Mechanics R&D (II)

Sun 8/21/16

ID	WBS	Task Name	Duration	Start	Finish	Cost Center	Fixed Cost	Cost	Text10	<div><div>2017</div><div>2018</div><div>2019</div><div>2020</div><div>2021</div></div>																							
98	1.5.2	Setup	5 days	Fri 1/25/19	Thu 1/31/19	LDRD	\$0.00	\$10,666.67		Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4							
99	1.5.3	Operations	20 days	Fri 2/1/19	Thu 2/28/19	LDRD	\$0.00	\$6,400.00																									
100	1.6	sPHENIX Mechanics Integration	42 days?	Wed 4/18/18	Thu 6/14/18		\$0.00	\$50,000.00																									
101	1.6.1	Final Mechanics Desgin	30 days?	Wed 4/18/18	Tue 5/29/18	LDRD	\$0.00	\$30,000.00																									
102	1.6.2	Mechanics Final Design Review	12 days	Wed 5/30/18	Thu 6/14/18		\$0.00	\$20,000.00																									
103	1.6.2.4	Mechanics Final Design Review	1 day	Wed 5/30/18	Wed 5/30/18	LDRD	\$0.00	\$2,000.00																									
104	1.6.2.5	Incorporate Review Comments	10 days	Thu 5/31/18	Wed 6/13/18	LDRD	\$0.00	\$16,000.00																									
105	1.6.2.5	Complete Final Mechanical Design	1 day	Thu 6/14/18	Thu 6/14/18	LDRD	\$0.00	\$2,000.00																									
106	1.7	MAPS Inner Barrel Review	12 days	Fri 6/15/18	Mon 7/2/18		\$0.00	\$28,000.00																									
110	1.8	Productions	661 days?	Wed 8/1/18	Wed 2/10/21		\$0.00	\$3,003,273.33	Production																								
144	1.9	Ready for beam	0 days	Wed 2/10/21	Wed 2/10/21		\$0.00	\$0.00																									



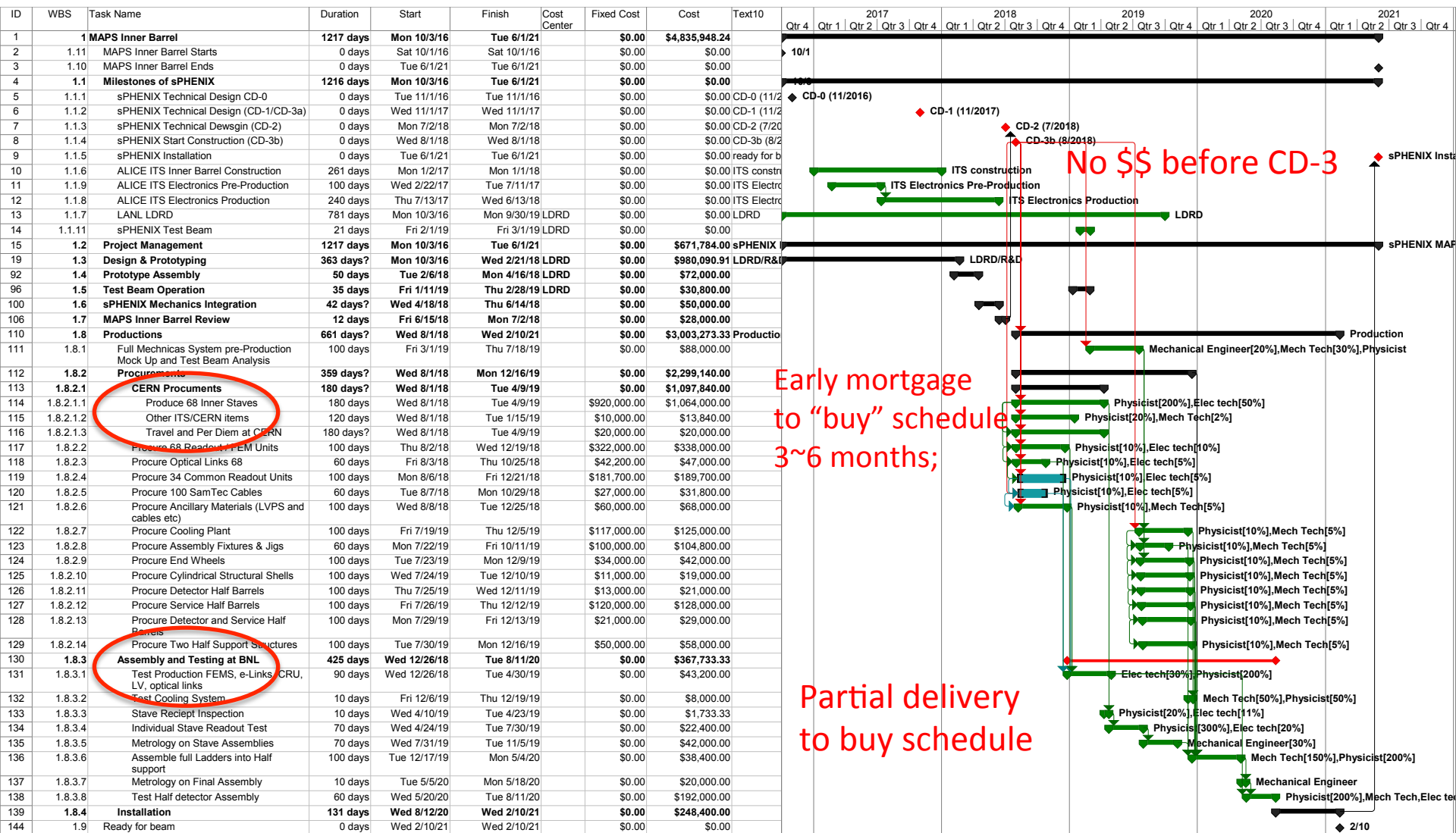
Ready for production  
at CD-3b, ~8/2018

Obtain DOE R&D fund after CD-1?



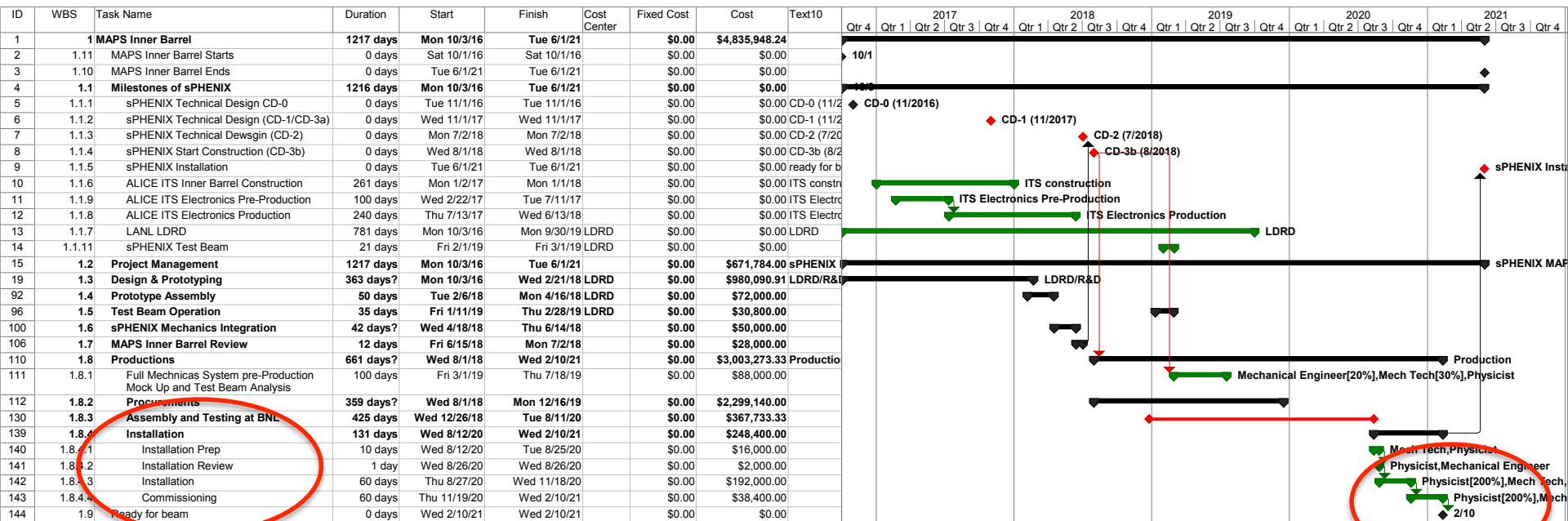
# Production & Assembly

Sun 8/21/16



# Installation and Commissioning

Sun 8/21/16



# Open Issues

- MoU with ALICE/CERN: by 12/2016?
  - Prototype and production stave production and delivery
  - Obtain design files, electronics and mechanics
  - Training sPHENIX personnel, manpower
  - R&D collaboration and schedule
  - Availability of CERN facilities after ITS production
- Schedule/funding gap of stave productions
  - ITS production: ~1/2017-1/2018
  - sPHENIX CD-3b: 8/2018
  - Risk Mitigation:
    1. early training through LDRD effort, maintain activity at low level
    2. Possible mortgage sPHENIX production from ALICE/CERN, MoU
    3. Seek external foreign funding?
- sPHENIX readout R&D
  - Possible delay due to unavailability of key elements like staves and readout for R&D
  - Risk mitigation:
    - early R&D in collaboration with ALICE as associate members

# Schedule Contingency and CDs

- Electronics R&D to meet CD1
  - Early procurements
  - Join effort with LBNL/ALICE
- Mechanical & cooling R&D to meet CD2/CD3
  - Early joint R&D with LBNL/MIT
- Production
  - Partial delivery to overlap task schedules with parallel efforts

# Risk Registry

- sPHENIX and ITS/ALICE schedules
  - R&D
  - Production
  - CERN facilities
  - Funding profile
- Long development time for readout boards etc.

# Backup slides

# Projected Future sPHENIX Schedule

Slide from Ed O'Brien 6/24/2016

CD-0	Sept-Oct 2016
Director's Cost and Schedule Review	Late Fall 2016
Test Beam at FNAL(2 <sup>nd</sup> round prototyping)	Jan 2017
OPA-CD-1/CD-3a Review	May-Jun 2017
CD-1/CD-3a authorization	Nov 2017
All Preproduction R&D and Design complete	May-Jun 2018
OPA- CD-2/CD-3b review	May-Jun 2018
CD-2/CD-3b authorization	Jul-Aug 2018
sPHENIX Installed, cabled, ready to commission	Apr 2021
First RHIC beam for sPHENIX	Jan 2022

The current Resource-loaded Schedule contains **8.5 months of float** to Jan 2022

# LANL/sPHENIX – ALICE Collaboration

**From:** Luciano Musa <[luciano.musa@cern.ch](mailto:luciano.musa@cern.ch)>

**Date:** Saturday, August 6, 2016 at 9:25 PM

**To:** "Ming Liu (LANL)" <[ming@bnl.gov](mailto:ming@bnl.gov)>

**Subject:** Re: ALICE ITS MAPS project and sPHENIX - ALICE Associate Membership?

Dear Ming,

sorry for the late reply to your previous e-mail. We had two Engineering Design Reviews (mechanics and cooling) and then I was in Jakarta for one week for an ITS Asian Meeting.

I am glad to learn that you succeed obtaining a \$5M grant (congratulations!!) and your plans to become an ALICE associate member to work in the ITS project. This will require a detailed discussion between the two of us for the preparation of an MoU.

I am leaving today for two weeks of vacation and will be back to CERN on August 22nd. I would propose we get in touch on the 22nd or 23rd August, if this is fine for you.

A possible timeline is presentation of your request at the MB of 1st September and at the CB of 11th November.

Kind Regards,  
Luciano

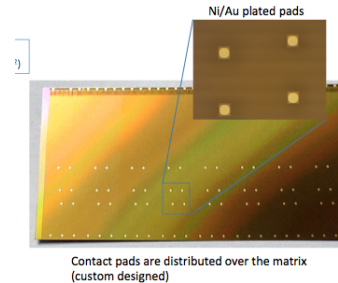
**Plan: ITS/ALICE associate members by the end of 2016**



# Critical R&D through LDRD

## Extend TowerJazz Production:

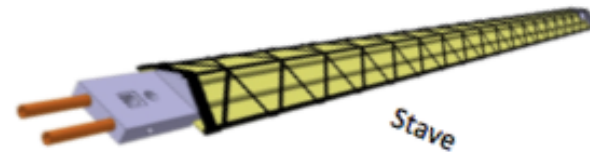
In-kind contribution  
525 ALPIDE-final sensors  
(inner 3 layers plus ~20% spares)



2x525 ct.

## Test Beam Prototype:

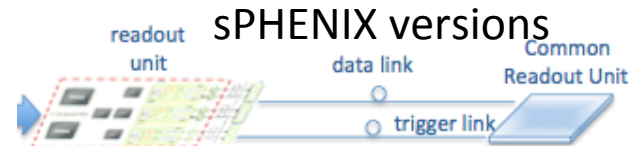
4 full inner ALICE ITS Staves  
ALICE readout + common readout boards  
small scale power & cooling, jigs, etc



4 ct.

## Readout Design:

new FEM design for sPHENIX,  
replace the ALICE readout board  
full-system test with test beam prototype

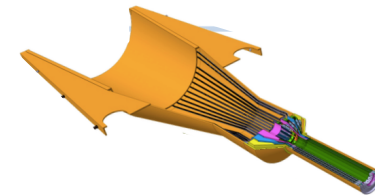


4 ct.

## Half-Barrel Mechanical Design:

adapt ALICE inner 3 layer mechanics to sPHENIX  
build 3-layer mounts for full-system test

sPHENIX versions



2 ct.

## Under LDRD funding:

- Final Detector ~10% populated with staves & readout
- CERN-trained personnel
- Reduce cost of MAPS detector by \$2M!

# Proposed Path Forward

- Take advantage of ALICE/ITS production
  - Obtain fully tested staves + 40% spares, right after the end of ITS production (~1/2018)
- Setup an initial MOU with ALICE to proceed with the collaborative effort(10/2016)
  - engage LANL/sPHENIX personnel from the beginning on Stave assembly and testing etc.

# Tracker Review Charge - revised

**Expect a sentence to be added to the charge asking for an evaluation of whether the Tracker design and performance parameters will enable the sPHENIX Physics program to be successfully carried out.**

**The review will include an examination of the following specific items:**

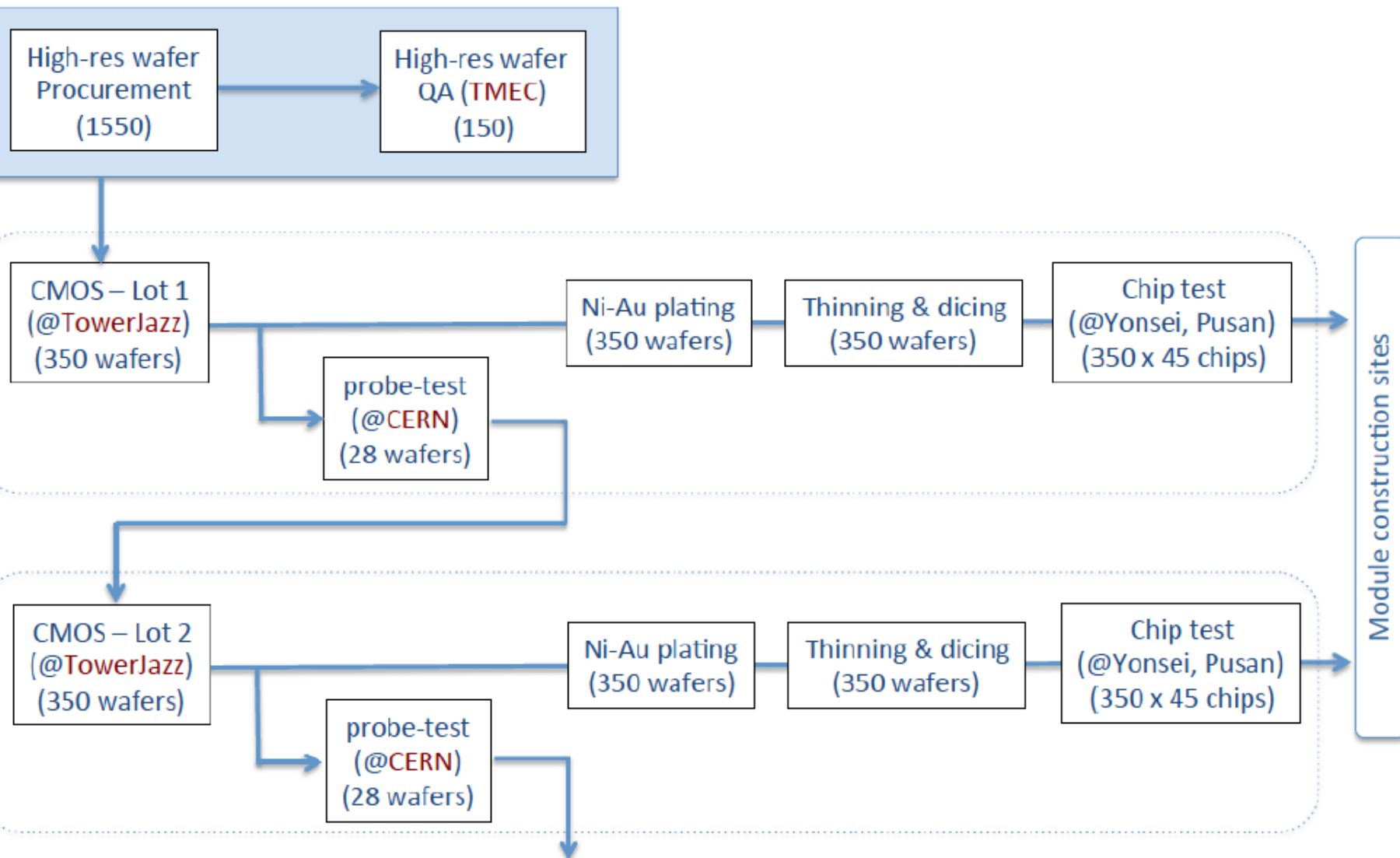
- 1. Technical Design:** Have the physics requirements driving the design specifications of the sPHENIX tracking detector been properly addressed in the detector design and planning? Are the tracking scope and specifications sufficiently well defined to support the preliminary cost and schedule estimates? Has a viable process and schedule for any anticipated significant technology down-selects been put forward? If so, does it realistically conform to the project's schedule constraints?
- 2. Cost and Funding:** Are the cost estimates for each of the sub-detectors reasonable? Have the various funding sources and institutional resources been identified in each of the cases, and have any necessary assumptions been properly incorporated into the planning and presented? Do the estimates in the initial resource loaded schedules contain all of the staffing and other resources needed in order to execute the subprojects?
- 3. Schedule:** Are the schedules realistic and achievable? If not, how can this be remedied or addressed? Does the project schedule for each of the sub-detectors properly take into consideration all necessary activities associated with detector realization – i.e., design, R&D, prototyping, beam tests and analysis requirements, feedback to the design, and final design and construction?
- 4. Management:** Is there a viable plan for the roles and responsibilities of the institutions involved in the different subprojects? Has the staffing at these institutions been identified? Do the proposed institutions/detector collaborations have the expertise and sufficient available research time to execute the projects on the envisioned time scales? Can viable subproject collaborations be assembled in the time available?
- 5. Risk:** Have the principal risks been identified and associated mitigation plans been developed? If not, where are the most notable deficiencies and vulnerabilities? Are there modifications to the design and/or R&D campaigns that might significantly reduce the principal risks?
- 6. Open Issues:** Are there any unidentified open design or fabrication issues that require additional attention?

# Inputs from ALICE ITS Project

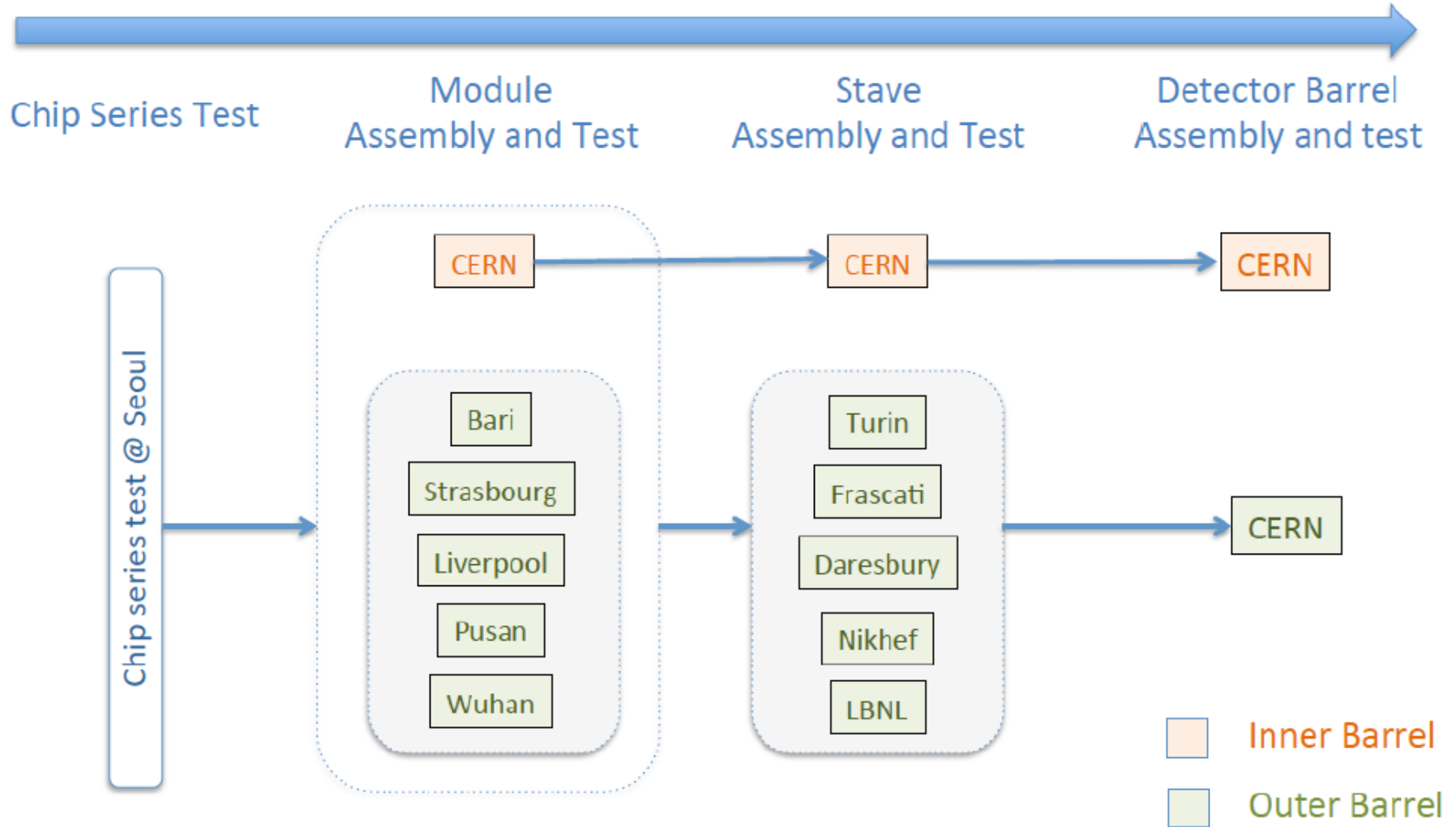
## 4/1/2016

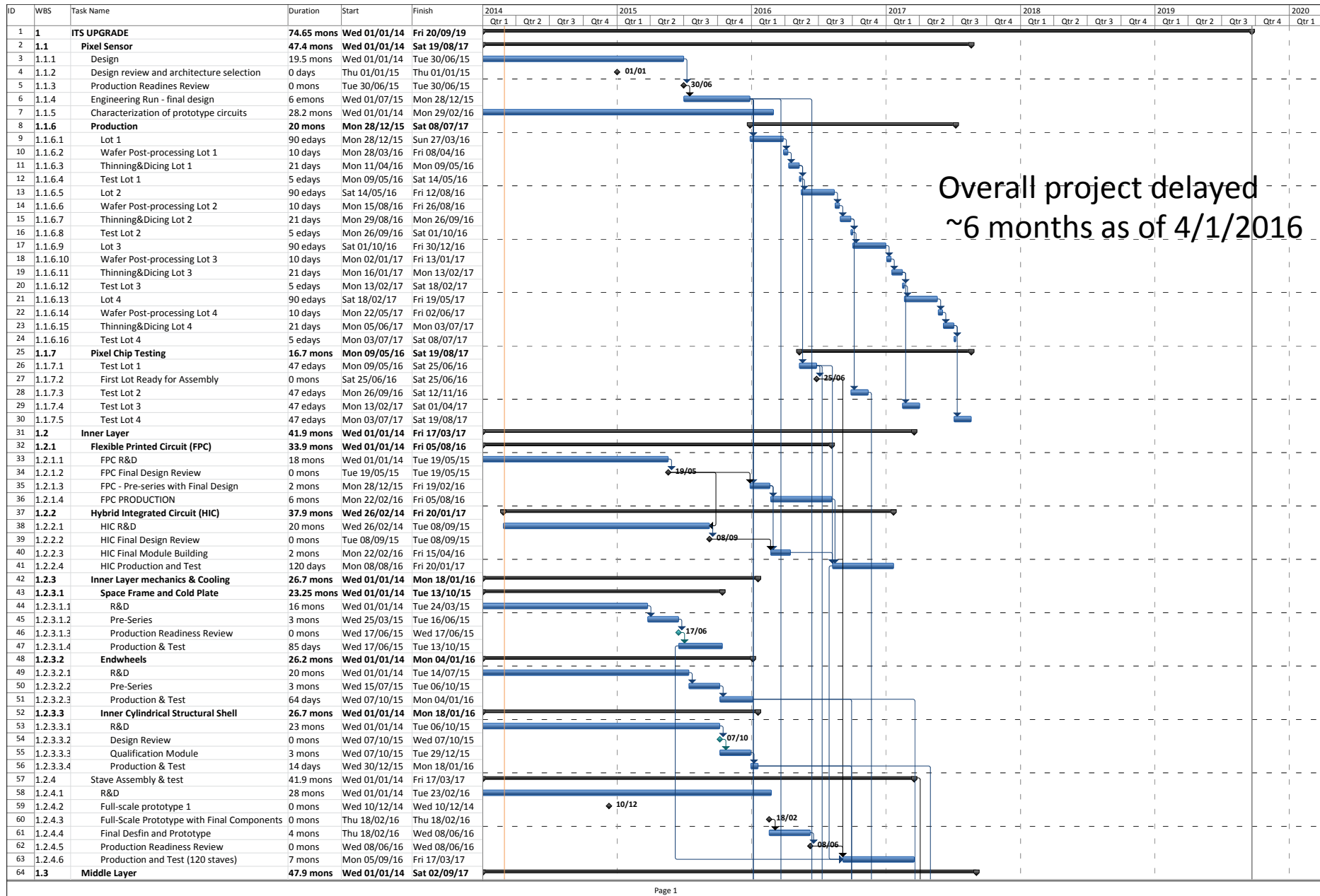
- 1) Project Schedule, add 6 months delay
- 2) Cost and FTEs

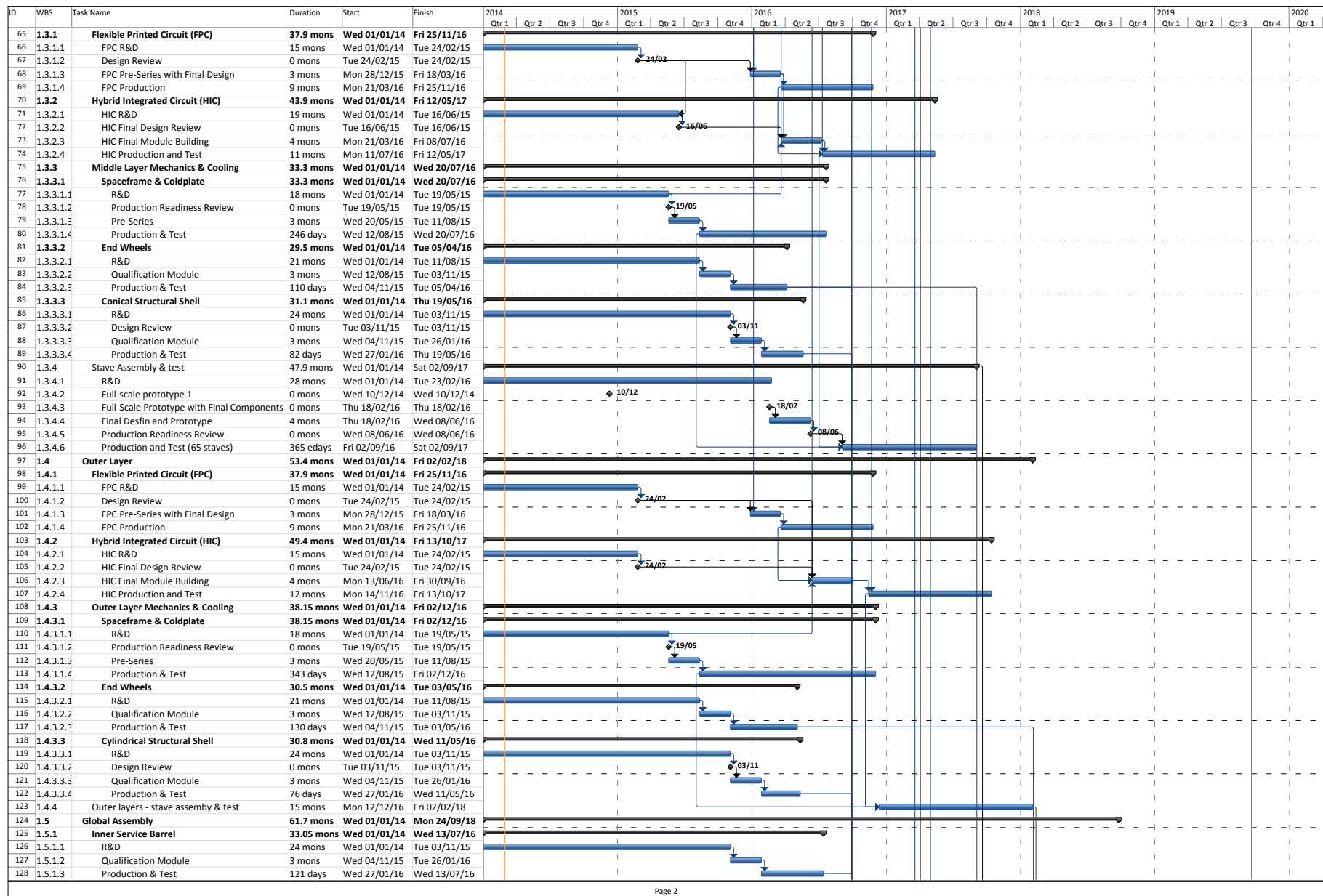
# Pixel chip production flow chart



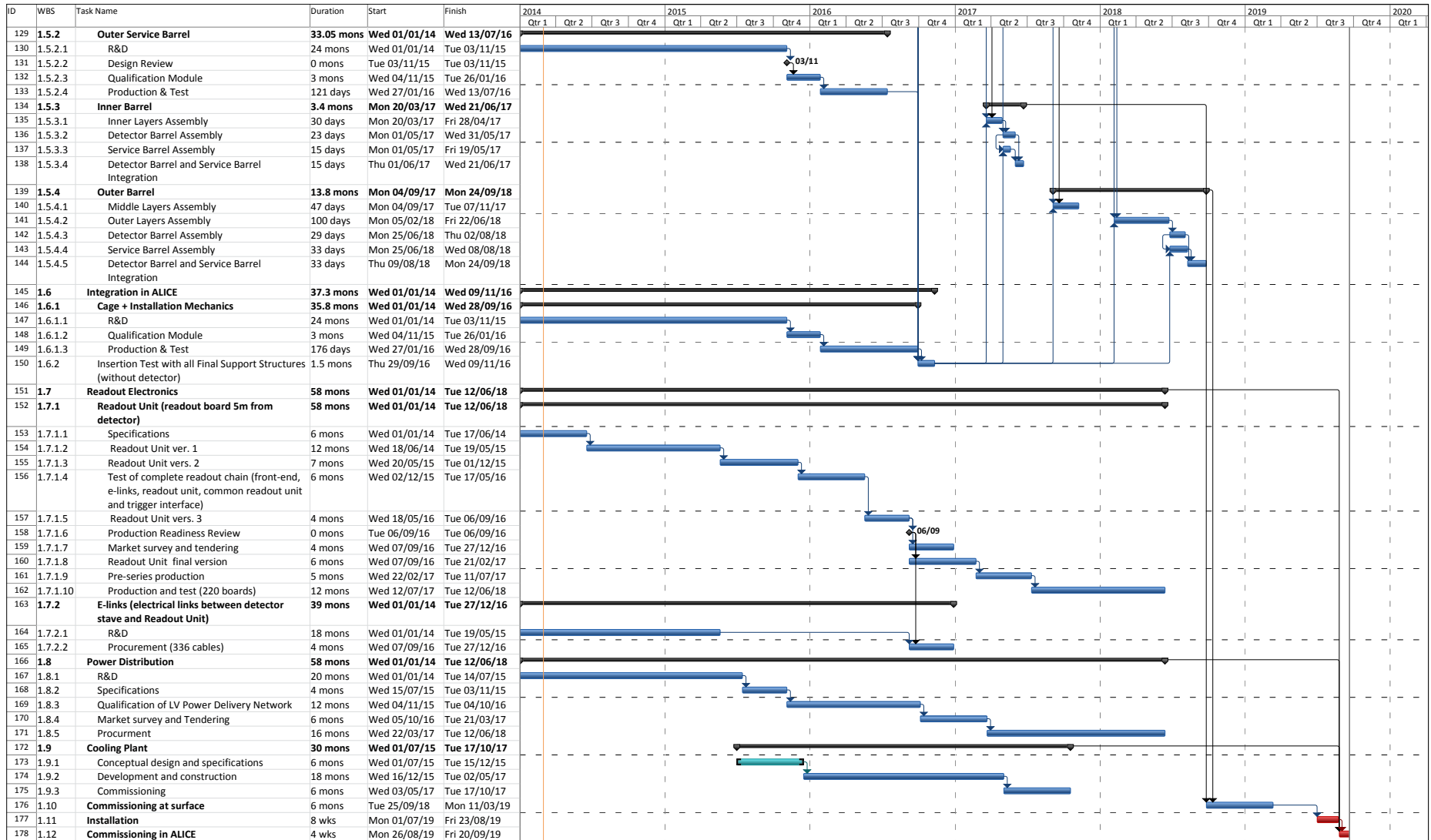
# Module and Stave production flow chart

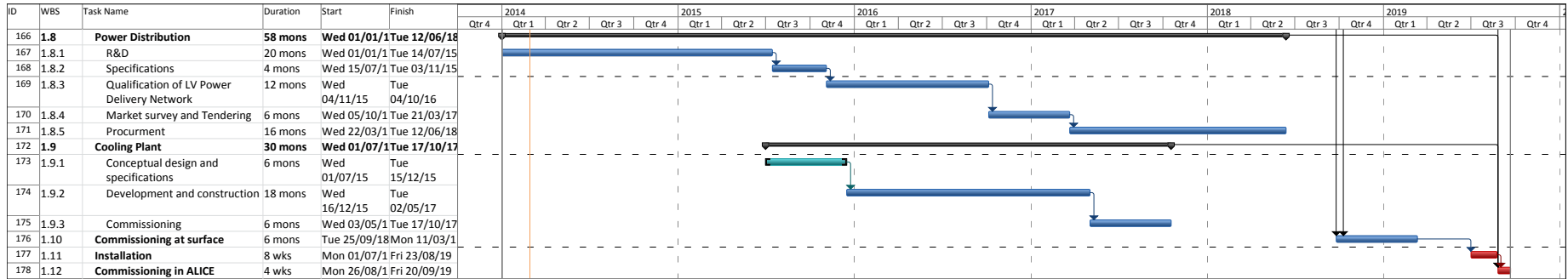






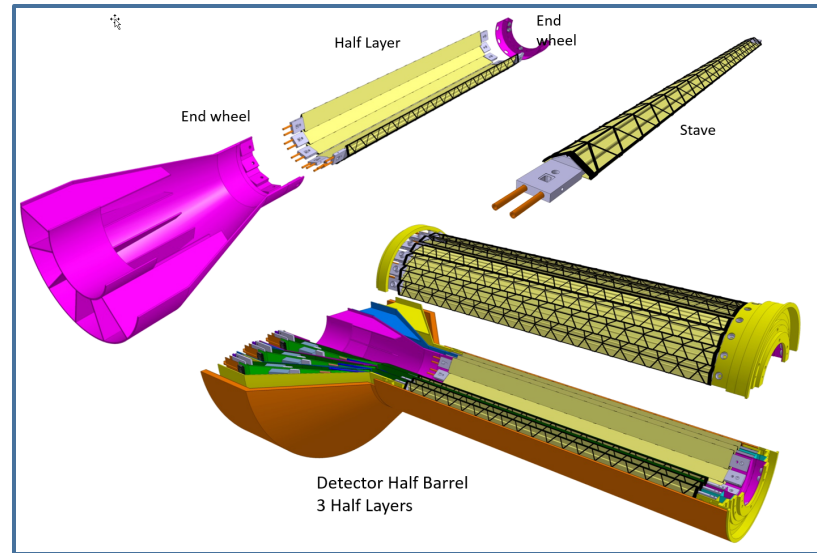
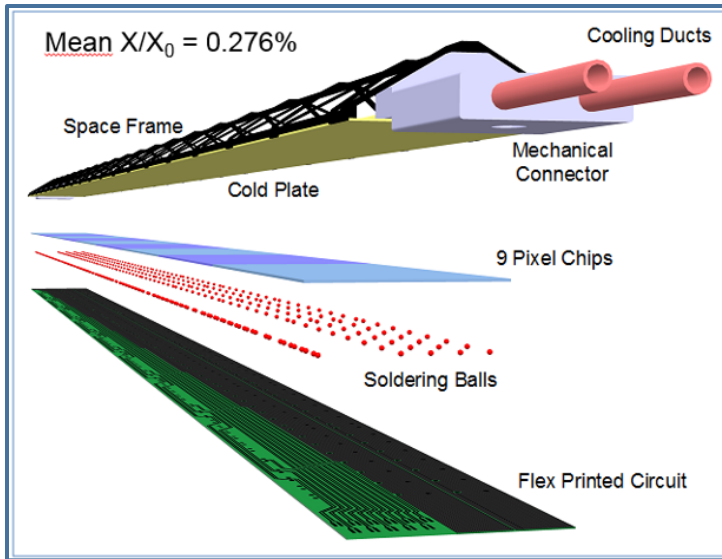






# Input from STAR/HFT from Leo 4/1/2016

# ITS Inner Layers vs PXL/STAR HFT



48 inner staves

Readout for: ➡

- 432 Sensors
- 226 M pixels
- $0.19 \text{ m}^2$  of silicon

Very comparable to PXL

# STAR/HFT PXL Cost and schedule

Taken at CD-3

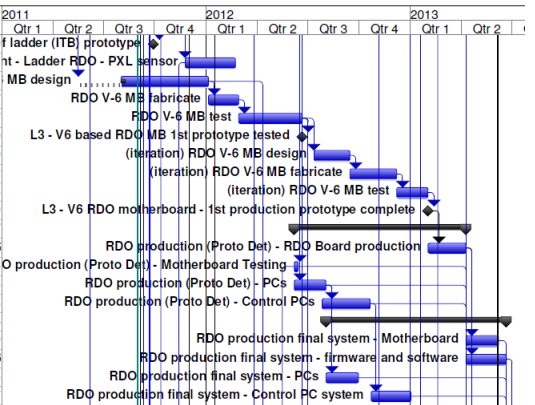
WBS	Task Name	Cost (\$K)
<b>1.2</b>	<b>Pixel Detector (PXL)</b>	<b>4,993</b>
1.2.1	Pixel Mechanics	1,210
1.2.2	Pixel Electronics	3,043
1.2.3	Detector Assembly	225
1.2.4	Infrastructure	515

- The cost for WBS 1.2.2.6 Readout Electronics is \$800k
- Production RDO boards are ~\$4.9k/board in quantities of 50.
- Most of the firmware and software was done by non-(project)costed people
- Full cost book to show detailed cost is available (distributed with slides in separate file).

# PXL Cost and schedule

Taken at CD-3

ID	WBS	Task Name	% Complete	Duration	Start	Finish	Free Slack	Estimate Basis	Cost	2011	2012				2013				
										Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2
223	1.2.2.6.1.5	L3 - Full RDO of ladder (ITB) prototype	0%	0 days	6/28/11	6/28/11	972.75 days		\$0.00										
224	1.2.2.6.1.6	RDO Development - Ladder RDO - PXL sensor	0%	63 days	8/25/11	11/22/11	91 days	EJ	\$108,364.61										
225	1.2.2.6.1.7	RDO V-6 MB design	5%	109.58 days	2/15/11	10/5/11	0 days	EJ	\$64,399.01										
226	1.2.2.6.1.8	RDO V-6 MB fabricate	0%	36 days	10/5/11	11/28/11	0 days	EJ	\$77,966.47										
227	1.2.2.6.1.9	RDO V-6 MB test	0%	75 days	11/28/11	3/21/12	0 days	EJ	\$26,332.27										
228	1.2.2.6.1.10	L3 - V6 based RDO MB 1st prototype tested	0%	0 days	3/21/12	3/21/12	793.17 days		\$0.00										
229	1.2.2.6.1.11	(iteration) RDO V-6 MB design	0%	45 days	4/11/12	6/14/12	0 days	EJ	\$8,347.09										
230	1.2.2.6.1.12	(iteration) RDO V-6 MB fabricate	0%	58.33 days	6/14/12	9/6/12	0 days	EJ	\$45,545.62										
231	1.2.2.6.1.13	(iteration) RDO V-6 MB test	0%	40 days	9/6/12	11/1/12	0 days	EJ	\$17,249.58										
232	1.2.2.6.1.14	L3 - V6 RDO motherboard - 1st production prototype complete	0%	0 days	11/1/12	11/1/12	0 days		\$0.00										
233	1.2.2.6.2	RDO production (Proto Det)	0%	207.91 days	3/7/12	1/8/13	184 days		\$160,776.47										
234	1.2.2.6.2.1	RDO production (Proto Det) - RDO Board production	0%	39 days	11/1/12	1/8/13	0 days	EJ	\$112,572.15										
235	1.2.2.6.2.2	RDO production (Proto Det) - Motherboard Testing	0%	5 days	3/7/12	3/13/12	0 days	EJ	\$1,206.43										
236	1.2.2.6.2.3	RDO production (Proto Det) - PCs	0%	41 days	3/7/12	5/2/12	0 days	EJ	\$33,864.26										
237	1.2.2.6.2.4	RDO production (Proto Det) - Control PCs	0%	60 days	4/26/12	7/20/12	0 days	EJ	\$13,133.63										
238	1.2.2.6.3	RDO production final system	0%	216.91 days	5/3/12	3/21/13	72.09 days		\$155,180.28										
239	1.2.2.6.3.1	RDO production final system - Motherboard	0%	40 days	1/8/13	3/7/13	10 days	EJ	\$96,354.79										
240	1.2.2.6.3.2	RDO production final system - firmware and software	0%	50 days	1/8/13	3/21/13	0 days	EJ	\$11,822.66										
241	1.2.2.6.3.3	RDO production final system - PCs	0%	41 days	5/3/12	6/29/12	175.91 days	EJ	\$33,864.26										
242	1.2.2.6.3.4	RDO production final system - Control PC system	0%	50 days	7/23/12	10/1/12	111.91 days	EJ	\$13,138.57										



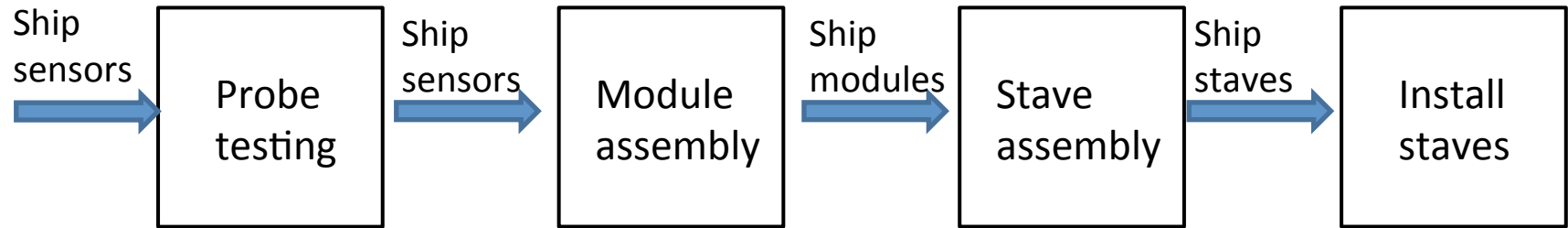
- 22 months - From initial RDO board design to delivery of all production RDO boards.
- We co-developed the earlier generations of sensors with the earlier generations of RDO so the firmware and software modules are often common to generations.
- Contributed resources are not counted in the project schedule document (firmware and software).

# PXL RDO lessons learned

- Co-development of sensors and RDO was very useful. The architecture and code base is well tested and vetted with the sensors over generations and less likely to contain surprises.
- The production RDO system was designed to be the base for all testing. Beam tests, probe testing and other production testing. This unified our code base and simplified our hardware needs.
- Close attention should be paid to the interfaces and architecture that you are interfacing to. Allow extra time to find incompatibilities.
- A significant system test (at least a few chains) with beam and interfaced to the rest of the full DAQ, slow controls, etc. is highly desirable to uncover system level problems.
- The cost drivers for us were multiple design iterations of the production RDO boards, the interlock systems, the software and scripts for the interface to the STAR run and experiment control systems.
- Build in flexibility that will allow you to address unforeseen problems. Our LU damage problem was solved with the current limiting threshold and remote voltage adjustment capabilities built into the system.

# Workflow overview

Leo's talk



- This is a draft overview of the workflow for building middle and outer layer staves.
- For this draft, we assume wire bonding for the interconnection technology.
- For this draft, we assume the tabbed version of the FPC.
- We are specifying a baseline workflow and will update as the sequences become more developed.
- Not all processes are fully developed.
- In the shipping stages, the barcode information for each item is stored in the database.



# **sPHENIX MAPS Cost & Schedule Workfest**

## **Draft Cost & Schedule Document and Project File**

David M Lee

Guest Scientist, Los Alamos National Laboratory

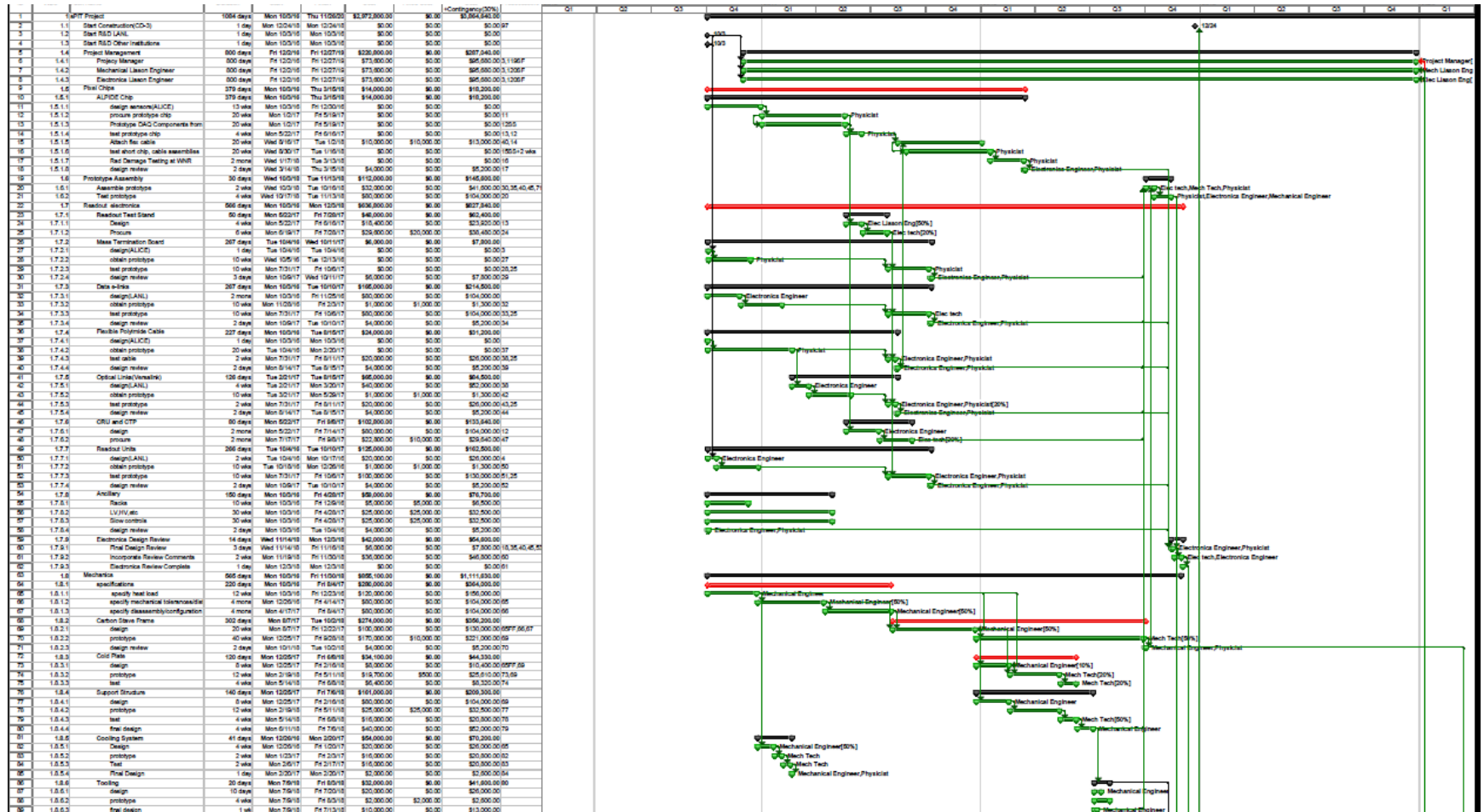
# Assumptions

- Copy ALICE Inner Tracker
- Some Initial Costs From ALICE Documents where available
- Other Costs from Previous Experience(Mine)
- Manpower costs from Lab Engineers and Techs
- Durations are My estimates
- No Manpower Smoothing
- No Schedule contingency
- Applied 30% cost contingency
- Will Follow DOE CD Process

# Inner Tracker Properties

- 48 Staves
- 432 Chips
- 27 cm long
- 3 layers: radii = 22mm, 31 mm, 39 mm
- Silicon Wafer: 18 chips/wafer, \$2330/wafer
- Dicing: \$520/wafer
- Inner Tracker needs (20% spares) 29 wafers

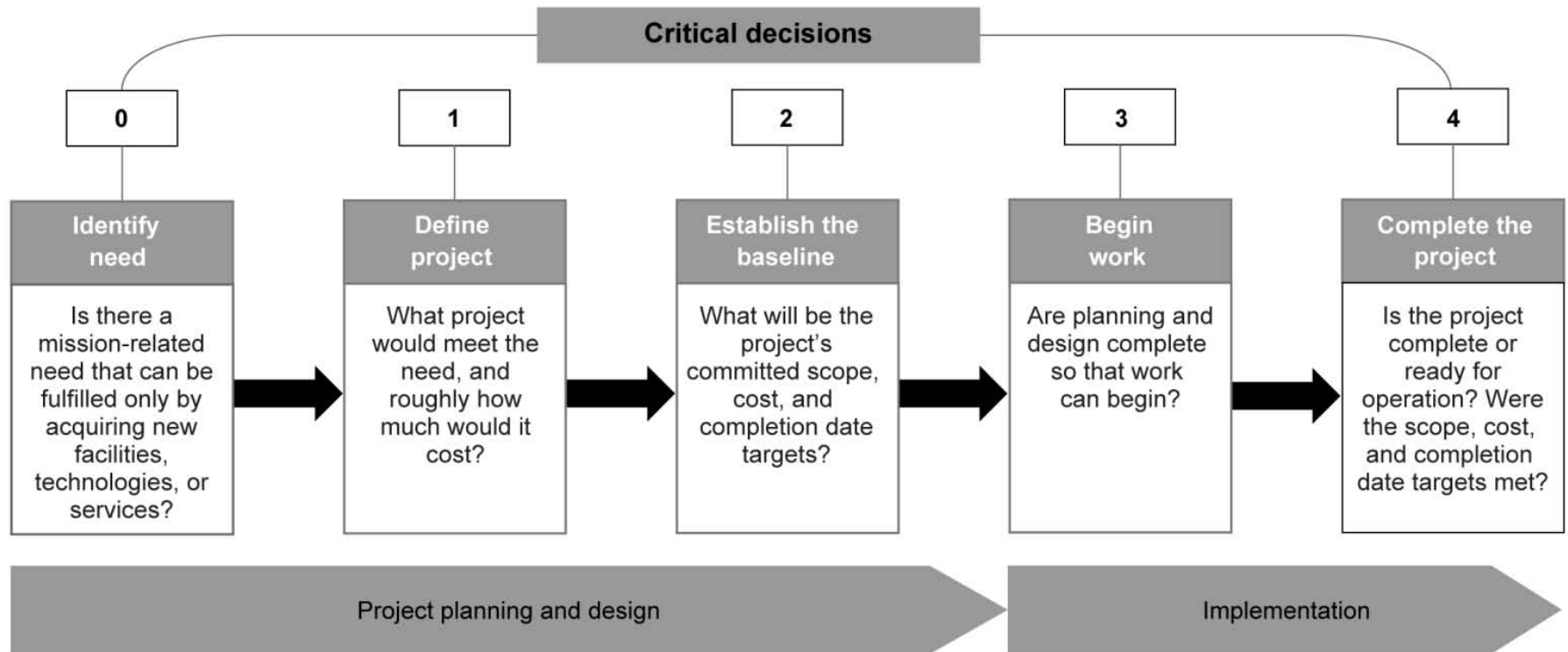
# Project File



# Sample Electronics Subtasks

ID	WBS	Task Name	Duration	Start	Finish	Cost	Fixed Cost	Cost +Contingency(30%)
1	1	sPIT Project	1084 days	Mon 10/3/16	Thu 11/26/20	\$2,972,800.00	\$0.00	\$3,864,640.00
2	1.1	Start Construction(CD-3)	1 day	Mon 12/24/18	Mon 12/24/18	\$0.00	\$0.00	\$0.00
3	1.2	Start R&D LANL	1 day	Mon 10/3/16	Mon 10/3/16	\$0.00	\$0.00	\$0.00
4	1.3	Start R&D Other Institutions	1 day	Mon 10/3/16	Mon 10/3/16	\$0.00	\$0.00	\$0.00
5	1.4	Project Management	800 days	Fri 12/2/16	Fri 12/27/19	\$220,800.00	\$0.00	\$287,040.00
9	1.5	Pixel Chips	379 days	Mon 10/3/16	Thu 3/15/18	\$14,000.00	\$0.00	\$18,200.00
19	1.6	<b>Prototype Assembly</b>	30 days	Wed 10/3/18	Tue 11/13/18	\$112,000.00	\$0.00	\$145,600.00
22	1.7	Readout electronics	566 days	Mon 10/3/16	Mon 12/3/18	\$636,800.00	\$0.00	\$827,840.00
23	1.7.1	<b>Readout Test Stand</b>	50 days	Mon 5/22/17	Fri 7/28/17	\$48,000.00	\$0.00	\$62,400.00
24	1.7.1.1	Design	4 wks	Mon 5/22/17	Fri 6/16/17	\$18,400.00	\$0.00	\$23,920.00
25	1.7.1.2	Procure	6 wks	Mon 6/19/17	Fri 7/28/17	\$29,600.00	\$20,000.00	\$38,480.00
26	1.7.2	<b>Mass Termination Board</b>	267 days	Tue 10/4/16	Wed 10/11/17	\$6,000.00	\$0.00	\$7,800.00
27	1.7.2.1	design(ALICE)	1 day	Tue 10/4/16	Tue 10/4/16	\$0.00	\$0.00	\$0.00
28	1.7.2.2	obtain prototype	10 wks	Wed 10/5/16	Tue 12/13/16	\$0.00	\$0.00	\$0.00
29	1.7.2.3	test prototype	10 wks	Mon 7/31/17	Fri 10/6/17	\$0.00	\$0.00	\$0.00
30	1.7.2.4	design review	3 days	Mon 10/9/17	Wed 10/11/17	\$6,000.00	\$0.00	\$7,800.00
31	1.7.3	<b>Data e-links</b>	267 days	Mon 10/3/16	Tue 10/10/17	\$165,000.00	\$0.00	\$214,500.00
32	1.7.3.1	design(LANL)	2 mons	Mon 10/3/16	Fri 11/25/16	\$80,000.00	\$0.00	\$104,000.00
33	1.7.3.2	obtain prototype	10 wks	Mon 11/28/16	Fri 2/3/17	\$1,000.00	\$1,000.00	\$1,300.00
34	1.7.3.3	test prototype	10 wks	Mon 7/31/17	Fri 10/6/17	\$80,000.00	\$0.00	\$104,000.00
35	1.7.3.4	design review	2 days	Mon 10/9/17	Tue 10/10/17	\$4,000.00	\$0.00	\$5,200.00
36	1.7.4	<b>Flexible Polyimide Cable</b>	227 days	Mon 10/3/16	Tue 8/15/17	\$24,000.00	\$0.00	\$31,200.00
37	1.7.4.1	design(ALICE)	1 day	Mon 10/3/16	Mon 10/3/16	\$0.00	\$0.00	\$0.00
38	1.7.4.2	obtain prototype	20 wks	Tue 10/4/16	Mon 2/20/17	\$0.00	\$0.00	\$0.00
39	1.7.4.3	test cable	2 wks	Mon 7/31/17	Fri 8/11/17	\$20,000.00	\$0.00	\$26,000.00
40	1.7.4.4	design review	2 days	Mon 8/14/17	Tue 8/15/17	\$4,000.00	\$0.00	\$5,200.00
41	1.7.5	<b>Optical Links(Versalink)</b>	126 days	Tue 2/21/17	Tue 8/15/17	\$65,000.00	\$0.00	\$84,500.00
42	1.7.5.1	design(LANL)	4 wks	Tue 2/21/17	Mon 3/20/17	\$40,000.00	\$0.00	\$52,000.00

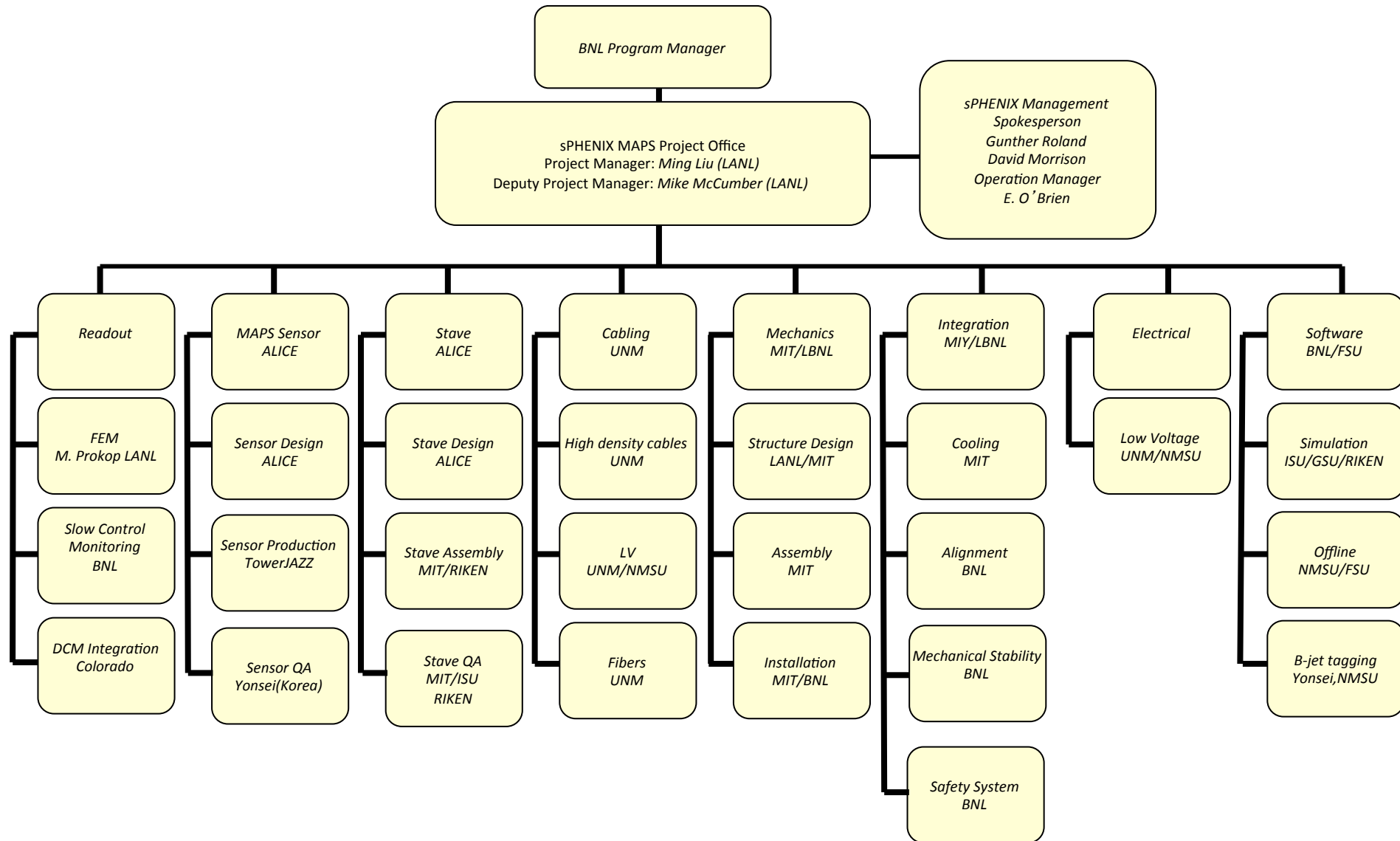
# DOE Critical Decision Process



Sources: GAO and DOE.

**GAO-13-129 DOE Nonmajor Projects**

# Organization Chart



# Forming the Collaboration

- **On board:**  
LANL, MIT, UNM, RIKEN, NMSU, BNL, Colorado, ISU, GSU
- **Potential:**  
LBNL, UCR, UC Davis, UCLA, Korean Institutes
- **Consulting:**  
ALICE/CERN, Yonsei/Korea, CCNU/China



## Resources I

- 1. LANL:
- Supported by LDRD (FY17-19), will develop a 4-stave MAPS prototype to fully test the readout chain from MAPS to sPHENIX DAQ, and also initial mechanical design.
- Provide electronics and mechanical engineering support through LDRD at least.
- 2. MIT:
- Both HI and ME groups are joining the MAPS efforts, strong physics and engineering capabilities (Bates Center); extensive experience on technical integration and cooling system, worked on STAR HFT in collaboration with LBNL.
- already have many students and postdocs working at CERN, could help on MAPS stave assembly and testing at CERN;
- Could lead the stave assembly and testing at CERN and BNL, cooling and mechanical integration effort
- 3. LBNL:
- Extensive experience in mechanical carbon structure and MAPS readout electronics, worked on PHENIX/ FVTX carbon frame supporting structure, already have test stand developed for the on-going ALICE MAPS upgrade project, will make a decision soon on joining the sPHENIX project.
- Could lead the mechanical carbon support structure, assembly and testing of staves etc
- 4. BNL:
- Strong technical capabilities in mechanical structure and DAQ, computing, slow control, safety and tech support, could lead the MAPS “Services” tasks;

## Resources II

- 5. Univ. of Colorado
- Extensive experience with DAQ electronics, DCM-II and slow controls, close to LANL for collaborative work, excellent physics and simulation capabilities
- Could lead the DAQ DCM-II integration effort and simulation work
- 6. ISU
- Plan to add one postdoc to work on various MAPS related tasks and simulations, have several students
- Could take a major role on simulation effort, and testing MAPS
- 7. FSU
- Could continue to lead the tracking software effort, one graduate student
- 8. UNM
- Extensive experience through PHENIX Muon Tracker and FVTX projects on cabling, LV distribution and high density cables etc.
- Could lead effort on LV and cabling, design, testing and integration

## Resources III

- 9. NMSU
  - Extensive experience with software and simulations, LV/HV control system etc.
  - Could play a major role on simulations, heavy-flavor tagging and physics analysis, provide manpower for testing and assembly work
- 10. GSU
  - Strong physics interest in heavy flavor, could play a major role on simulations and analysis, capable to develop small electronics control system
- 11. UCLA
  - Interested in MAPS hardware and heavy flavor physics, could play a major role on MAPS prototype R&D work and simulations, will send one student to work on LANL's LDRD project
- 12. UCR/UCDavis
  - Interested in MAPS project, heavy flavor physics, have local "very cost effective" machine and electronics shop to fabricate small structures and devices
- 13. Yonsei/Korea
  - Leading ALICE MAPS QA, could contribute to the production QA of MAPS chips, simulations and analysis
- 14. RIKEN/RBRC
  - Interested in MAPS project, from simulation to stave assembly and testing.

## What Needs to Be Done?

- Define Owners of Tasks, i.e. who will do the work?
- Research Costs, Durations, and Resources for Accuracy
- Provide Documentation for the Cost estimates
- Estimate Contingency
- Provide Information to the Project Office
- Develop an Org Chart

# Summer Work and Beyond

- LDRD funded!
  - LDRD: 10/2016-9/2019
- MAPS test and integration @LANL
  - Standalone sPHENIX DAQ/DCM-II
  - MAPS readout R&D
- Update C&S for September 7-9 review
- BNL sPHENIX tracker review (Nov. 2016?)
- sPHENIX MAPS full proposal?
  - Build collaboration
  - Simulation and detector optimization
  - Full detector design, CD-1
  - Plan for construction, CD-3b

# Project Input to sPHENIX Descoping/Cost Reduction Exercise

Scenario A	$\Delta$	FY16 M\$	Scenario B	$\Delta$
two-layer MAPS inner barrel	+3.0	one-layer MAPS inner barrel	+2.1	
no reuse of VTX	-0.2	no reuse of VTX	-0.2	
reduce TPC readout	-0.5	reduce TPC readout	-0.5	
reduce EMCal segmentation	-1.8	reduce EMCal segmentation	-1.8	
reduce EMCal $\eta$ acceptance	-2.0	further reduce EMCal $\eta$ acceptance	-2.2	
reduce DAQ refresh	-0.5	reduce DAQ refresh	-0.5	
reuse beam-beam trigger counter	-0.5	reuse beam-beam trigger counter	-0.5	
Total	-2.5		Total	-3.6

Specifically for Scenario B in the attached document there are 4 main areas of cost reduction:

1. Reduce TPC readout channels from 200k to 100k - \$500k
2. Reduce EMCal through 4 to1 ganging of tower output -\$1800k
3. Reduce EMCal eta coverage to  $|\eta| < 0.7$  -\$2200k
4. Reduce DAQ/Trigger hardware -\$500k

Presume success in \$500k savings by obtaining a Trigger detector through an international collaborator or re-use of existing device

Presume the \$200k saved by not building VTX external support structure is in the MAPs cost estimate(?)

Could the appropriate L2 and L3 managers analyze the proposed cost savings and answer the following questions for each of the 4 items:

Answer by this Monday Jun 20

- Based on your best information are the cost savings reasonable?
- What is the schedule impact of the cut? It can be positive or negative.
- What if any additional technical risk will result from these cuts?

Specifically for the DAQ/Trigger, excluding the cut Trigger Device, the budget is cut from \$1.2M to \$0.7M.

Could Martin, Eric and Chi answer what would be purchased for \$0.7M and what would we have to forego?

## **Responsibilities (FVTX)**

The sensors will be a joint responsibility between US and the Prague group from the Czech Republic, with the Prague group doing the bulk of the R&D. A collaboration has been formed with the FNAL Engineering Dept., headed by Ray Yarema, for development of the FPHX chip.

The FNAL group has modified an existing operational FPIX2 chip to our specifications and will produce and test the new FPHX chips. Los Alamos National Laboratory (LANL) will oversee this effort.

The HDI will be a joint US institutional responsibility with University of New Mexico (UNM) leading the effort.

The sensor wedge assemblies are the responsibility of Columbia University. The cooling backplane will be purchased through an engineering firm, HYTEC.

# Status of sPHENIX Project Preparation

- Defined the subsystem Project scope
- Defined WBS categories (Det:Design, Prototyping, Production, Elec:Design, Prototyping, Production)
- Defined Project approach
  - Software choices: MS-Project for CD-1, Primavera for CD-2/3
  - Use standard CD-1, CD-2/3 approval dates for project planning purposes
  - No final design until CD-1 approval. No production start until CD-3. **All R&D MUST be done prior to CD-3.**
  - Set number of scheduled reviews (preproduction , safety, post prototype...), include 3 rounds of prototyping in most cases.
- Assign resources and durations to all tasks
  - All L3 manager 20% time just to manage. All L2 managers 50% time.
  - All procurements should have small amount of resources defined to follow orders.
- Procurement tasks
  - Orders < \$100k 1 month to place order
  - Orders < \$1M 3 month to place orders
  - Orders > \$1M 6 months to place orders
- All tasks are linked with predecessors and successors
- Material costs are assigned where appropriate
- Define labor bands are associated with the labor resources
- Analyze labor and budget profiles.



# sPHENIX Schedule Summary

## Project Schedule and Budget incorporating Review committee recommendations:

**CD-0**                      **Apr 2016 (keep for now but it will slip)**

**DOE approval to decommission PHENIX Apr 2016**

**Decommissioning starts immediately at the end of Run-16, mid Jun 2016**

**CD-1/CD-3a**                      **Nov 2017**

**CD-3b**                      **Jul 2018**

**Tracker fully assembled and tested. Ready for installation in 1008 Jan 2021.**

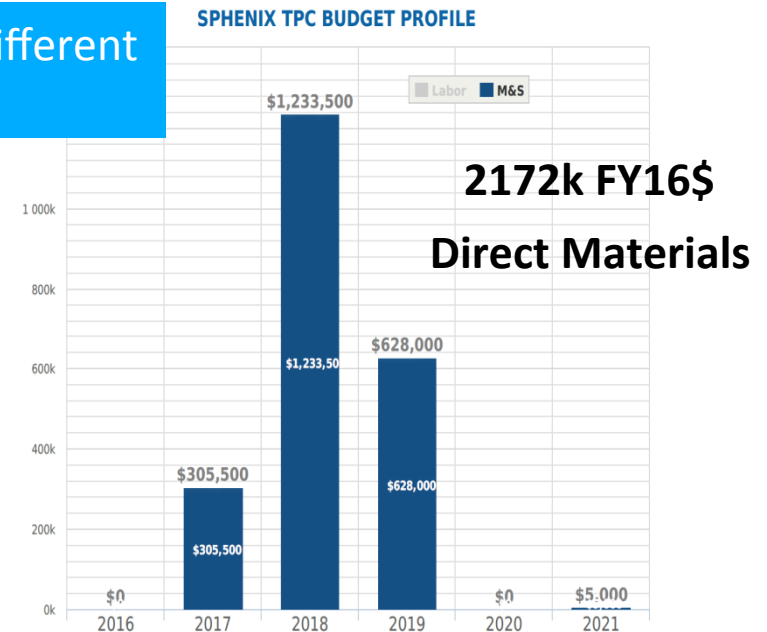
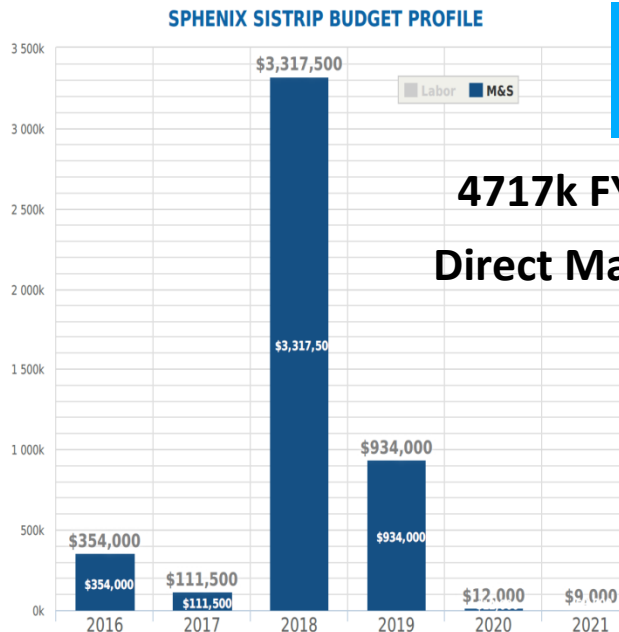
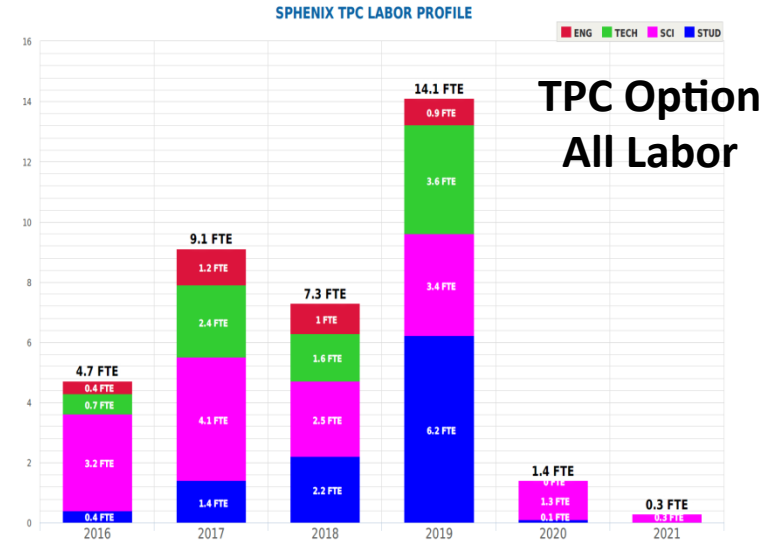
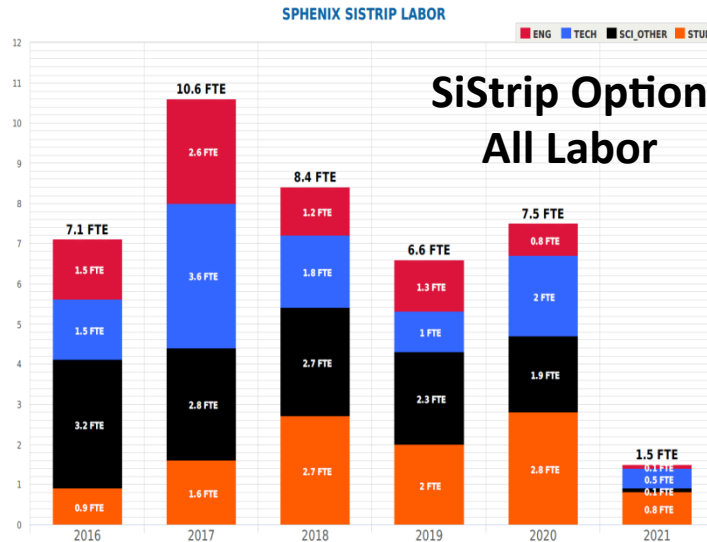
**sPHENIX installed commissioned and ready for beam Jun 2021.**

**First RHIC Beam for sPHENIX Jan 2022**

**CD-4**                      **Jan 2023**

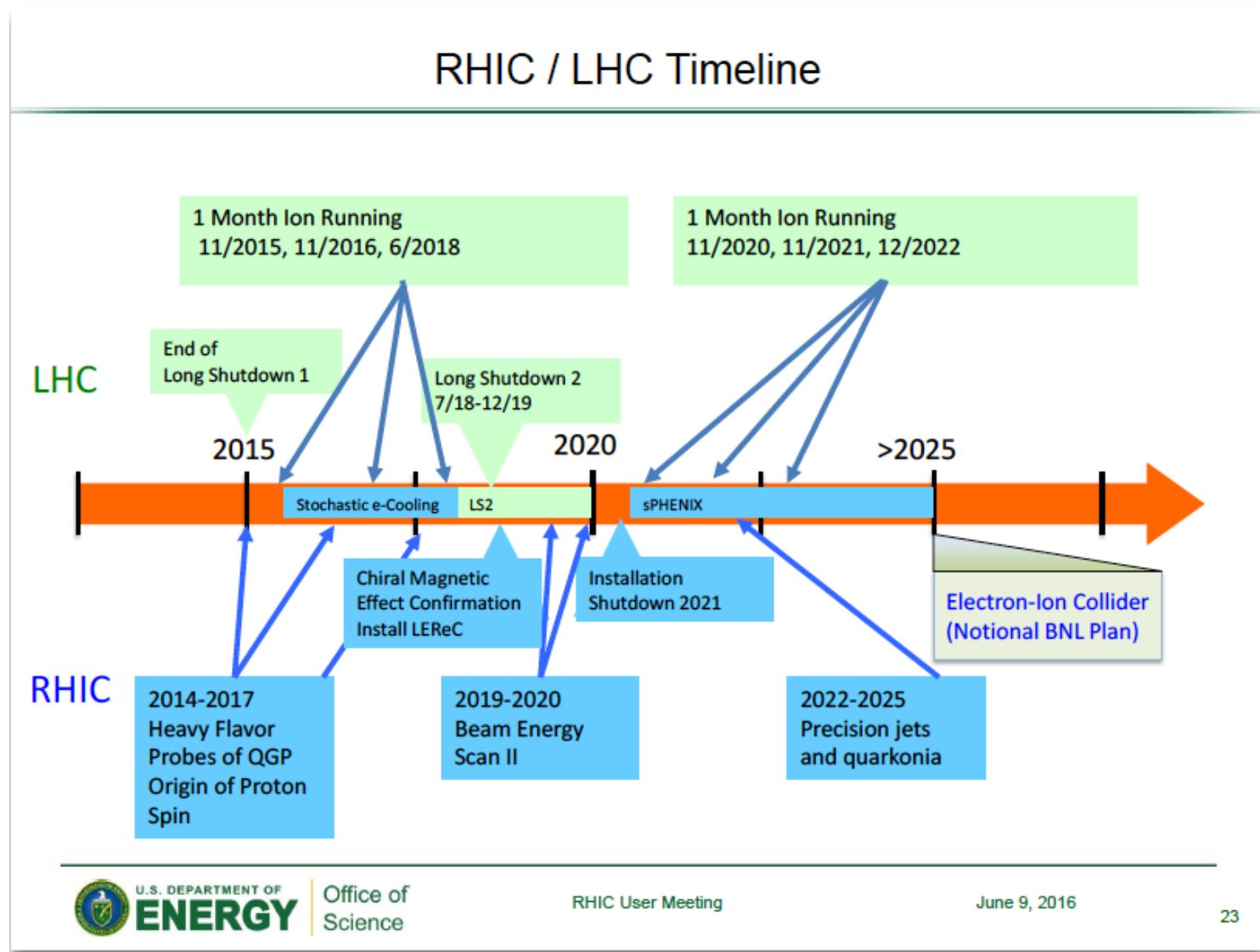
**The critical path for the project is through the Outer HCal. The schedule has 8.5 months of float to 1<sup>st</sup> beam Jan 2022.**

# Tracker Direct Materials and Labor FY16\$



Figures have different scales

# DOE's View on sPHENIX and other Long Term NP



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science

RHIC User Meeting

June 9, 2016

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